The Plankton and Profundal Benthic Macroinvertebrates of Gander Lake, Newfoundland

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by

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ABSTRACT

O'Connell, M.F. and Walsh, A. 2007. The plankton and profundal benthic macroinvertebrates of Gander Lake, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 2688: v + 110 p.

A seasonal quantitative study of plankton and a survey of profundal benthic macroinvertebrates were conducted during the open water period in Gander Lake (surface area = 11,320 ha, maximum depth = 280 m, mean depth = 105.4 m), the third largest lake in Newfoundland. Plankton samples were collected at three stations at selected depths ranging from the surface down to 250 m. Chrysophyta and Bacillariophyta dominated the net phytoplankton and substantial numbers were found in deep water, well below the euphotic zone. Diversity and abundance of zooplankton in Gander Lake were lower than previously reported for smaller and shallower lakes in Newfoundland and for large lakes elsewhere in North America. There is evidence of horizontal heterogeneity in abundance of zooplankton. Substantial populations were also present in deep water, including at the extreme depths sampled. Copepods dominated the microcrustacea the most important of which was *Leptodiaptomus minutus*. Abundance of most net phytoplankton and zooplankton taxa in 2003 was higher than in 2002. Abundance and diversity of profundal benthic macroinvertebrates were low, being comprised almost entirely of Chironomidae (Chironominae: *Sergentia*). The distribution of chironomids was contagious or clumped.

RÉSUMÉ

O'Connell, M.F. and Walsh, A. 2007. The plankton and profundal benthic macroinvertebrates of Gander Lake, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 2688: v + 2688 p.

Une étude quantitative saisonnière du plancton et une recherche sur les benthos abyssaux macro-invertébrés ont été réalisées pendant la période d'eau libre dans le lac Gander (superficie = 11 320 ha, profondeur maximum = 280 m, profondeur moyenne = 105,4 m), le troisième plus grand lac de Terre-Neuve. Les échantillons de plancton ont été recueillis dans trois stations, à des profondeurs sélectionnées variant de 0 à 250 m. Les chrysophycophytes et les bacillariophytes dominaient en termes de microphytoplancton, et d'importantes quantités ont été trouvées en eaux profondes, bien en deçà de la zone euphotique. La diversité et l'abondance de zooplancton dans le lac Gander étaient moins importantes que ce qui avait précédemment été démontré pour des lacs plus petits et moins profonds de Terre-Neuve et pour de grands lacs ailleurs en Amérique du Nord. Il existe des données probantes confirmant l'hétérogénéité horizontale relative à l'abondance de zooplancton. D'importantes populations étaient également présentes en eaux profondes, y compris dans les profondeurs extrêmes ayant fait l'objet de notre échantillonnage. Les copépodes dominaient les microcrustacés, le plus important étant le *Leptodiaptomus minutus*. L'abondance de la plupart des espèces de microphytoplancton et de zooplancton en 2003 était plus importante qu'en 2002. L'abondance et la diversité des benthos abyssaux macro-invertébrés étaient faibles; ils étaient composées presque entièrement de chironomes (Chironominae : *Sergentia*). Les chironomidés présentaient une distribution contagieuse ou en masses.

INTRODUCTION

While the phytoplankton (Palmer 1965; Davis 1972a, 1973; O'Connell 1974; Kerekes 1975, 1977; O'Connell and Andrews 1977, 1987; Earle et al. 1987; Scruton et al. 1987) and zooplankton (Cushman 1908; Davis 1972a, 1972b, 1973, 1975, 1976; O'Connell 1974; O'Connell and Andrews 1977, 1987; Ryan 1982, 1984; Chengalath and Koste 1983; Chengalath et al. 1984; Carter et al. 1986; Campbell and Knoechel 1988; Knoechel and Campbell 1988, 1992; Scruton et al. 1991; Gibbons 1993; Campbell et al. 1998; Campbell 2002) of many small lakes and ponds in Newfoundland have been studied in varying detail, the three largest lakes on the island (Fig. 1) have received very little attention. There is nothing for Grand Lake (the largest, surface area = 35,800 ha), one (zooplankton) study (Morry and Cole 1977) for Red Indian Lake (second largest, 18,044 ha), and the current study constitutes the only one for Gander Lake (third largest, 11,320 ha).

Compared to plankton, studies of benthic macroinvertebrates in Newfoundland lakes and ponds have been considerably fewer in number. Studies involving small water bodies include Dominy (1965), Wiseman (1970, 1971, 1972), O'Connell (1974), Ryan (1985), Gibbons (1993), Clarke (1995), and Clarke et al. (1997); the only information for large lakes other than the current study is that of Morry and Cole (1977) for Red Indian Lake.

The examination of plankton and benthic organisms in Gander Lake evolved as an adjunct to ongoing ecosystem based studies of fish populations (O'Connell and Dempson 2002; O'Connell et al. 2005; Power et al. 2005), to augment other information collected on the feeding ecology and trophic relationships of Arctic charr (*Salvelinus alpinus*). Therefore the studies were not designed to answer specific questions related to the plankton and benthos in and of themselves. The information culminating in this report however has been processed and analyzed well beyond the scope originally intended and as such is of sufficient magnitude and detail to warrant a separate treatment.

DESCRIPTION OF STUDY AREA

Gander Lake (48° 55' N, 54° 35 W) is located on the Gander River (Fig. 1), the third largest river system (catchment area = 6,398 km^2) in Newfoundland. Some morphometric features of the lake are presented in Table 1 and a bathymetric map is provided in Fig. 2. The known maximum depth (288 m) is approximately 270 m below sea level and the shape of the basin is consistent with the description of fiord lakes (Hutchinson 1957). The lake is oligotrophic and water is characteristically brown (O'Connell et al. 2005; Power et al. 2005). Average Secchi disc depth is around 3 m (O'Connell et al. 2005). The shoreline is mainly rocky with some gravely and sandy beaches.

In cold winters, the lake is ice covered from February until early spring (minimum daily temperatures lower than -20°C commonly occur and mean minimum daily temperature for the month of February can fluctuate around -15°C), but in warmer winters, the main body of the lake does not freeze. The lake is well oxygenated from surface to bottom throughout the year.

The Gander Lake watershed is underlain mainly by Palaeozoic (predominantly Ordovician with some Devonian) rocks. Soils are coarse to medium textured, well to imperfectly drained Orthic and Gleyed Humo-Ferric and Ferro-Humic Podzols with significant amounts of poorly drained Orthic Gleysols (Roberts 1983). Forests of *Abies balsamea* and a dense moss carpet of *Hylocomium splendens* predominate in areas not impacted by forest fires, but in areas subjected to burning, *Picea mariana* and to a lesser extent *Betula papyrifera* are found extensively (Damman 1983).

Fish species known to occur in Gander Lake in addition to Arctic charr are: anadromous and resident Atlantic salmon, *Salmo salar*, brook charr, *Salvelinus fontinalis*, resident rainbow smelt, *Osmerus mordax*, American eel, *Anguilla rostrata*, threespine stickleback, *Gasterosteus aculeatus*, and ninespine stickleback, *Pungitius pungitius*.

MATERIALS AND METHODS

All sampling stations in this investigation were located and accessed using coordinates obtained through the Global Positioning System (GPS). Station locations for plankton sampling are shown in Fig. 2. Plankton sampling depths at each station were chosen in relation to research results on the feeding relationships of the deep-dwelling morph of Arctic charr found in the lake (some down to a depth of 280 m) which showed evidence of a strong reliance on zooplankton as a food source (O'Connell et al. 2005; Power et al. 2005). Therefore the vertical distribution of zooplankton was of interest. Sampling intensity was tempered by the cost and resources required to collect and process samples. Consequently the maximum depth sampled at each station increased progressively in an exploratory manner over the duration of the study: July 11-24, 2002 – maximum = 30 m; August 8, 2002 – 50 m; August 28, 2002-July 4, 2003 – 100 m; July 22, 2003 – 150 m; August 7, 2003-October 1, 2003 – 200 m (stations 1 and 3) and 250 m (station 2). Collectively across all stations and sampling occasions, samples were taken at 0, 2, 5, 10, 15, 30, 50, 100, 150, 200, and 250 m depths. Sampling generally started at station 1 at around 0900 hours and ended at station 3 at approximately 1300 hours. Due to inclement weather or equipment failure, occasionally a station was not sampled on a particular trip. Station 3 was not sampled on October 9, 2002 and August 27, 2003; stations 1 and 3 were not sampled on October 1, 2003. Some samples also dried out in storage due to the failure of seals on jars (samples from the 100 and 150 m

depths at each of stations 1 and 2 and from 10 m at station 3, all collected on July 22, 2003).

Quantitative samples were collected with a modified Schindler-Patalas plankton trap (capacity of 42.5 litres) which was equipped with a filter cone and drain comprised of Nitex nylon monofilament screen cloth (mesh opening = 63 µm). A qualitative sample was collected at the surface at each station with a tow-net (constructed of the same screen cloth as used on the plankton trap) pulled slowly behind a boat. Samples were preserved in 10% formalin in the field. In the laboratory, under a fume hood, fluid contents were strained through a screen cloth with an aperture size of 30 µm and retained material placed in 80% ethanol for processing. Qualitative samples were always examined prior to quantitative samples in order to determine species composition. Quantitative analyses in the laboratory followed procedures outlined in Davis (1972a, 1973). The phytoplankton of the current study is the fraction retained in the 63 µm mesh of the plankton trap drain (net phytoplankton), which constitutes only a portion of the total species composition present (see later).

Benthic macroinvertebrate sampling locations are shown in Fig. 3. As with plankton, sampling stations were chosen in relation to findings on feeding relationships of the deep-water morph of Arctic charr which supplements its diet with benthic organisms. Two different areas of the lake were sampled. One was located in the western part of the lake and here sampling depths ranged from 43 to 60 m. The other was in the much deeper main body of the lake (sampling depths ranged from 199 to 280 m). The ten sampling stations in the western part of the lake were randomly chosen in an area approximately 0.64 km^2 in size located off Joe's Feeder tributary. The 30 stations in the main body ran longitudinally down the midline of the lake and were spaced 1 km apart. On September 23 and 29, 2004, stations 1-17 in the main body were sampled qualitatively with a bottom sled (equipped with a Nitex nylon monofilament cloth net with an aperture size of 500 µm) which was raised and lowered with a motorized winch. The winch assembly was also equipped with a depth meter. Quantitative samples were taken with a Petersen grab (sampling surface area of 1 ft^2 or 929 cm^2), again using the motorized winch. The grab was operated in conjunction with a Lowrance X136DF sonar. It was allowed to descend rapidly to within a few metres of the bottom then gently lowered onto the sediment. Stations 1-21 in the main body were sampled on July 6-7, 2005 and stations 22-30 on October 4, 2005; sampling in the western end was conducted on October 5, 2005. Samples were placed in large heavy gauge plastic bags in the boat for transport to shore where they were sifted using a wash bucket with a bottom consisting of stainless steel wire mesh (aperture size = 500 µm). Retained organisms were preserved in 80% ethanol in glass vials.

The General Linear Models (GLM) procedure of SAS (SAS Inst. 2003) was used to evaluate spatial and temporal distributions of the more important individual plankton taxa and various groupings of taxa. An initial attempt at using a three

factor model (with season, station, and depth as main effects plus interactions) was abandoned when the magnitude and nature of missing values imparted by the data structure described above failed to produce meaningful results. In order to minimize the influence of missing values, data were partitioned into four different seasons and a two-factor model applied to each season (with main effects station and depth and station x depth interaction). On the basis of sampling dates, the seasons were defined as follows: summer 2002 – July 11, July 24, August 8, August 28, and September 11; autumn 2002 – September 25, October 9, and November 13; spring 2003 – May 14, May 28, and June 12; summer 2003 – July 22, August 7, and August 27. Samples taken on October 1, 2003 (only station 2 was sampled) were omitted from the analyses. Preliminary analyses showed no significant station x depth interactions for individual taxa or groupings of taxa, consequently testing was limited to main effects only. Because of missing values, Type IV sums of squares were used to evaluate test results (Milliken and Johnson 1984). Least squares means (LSMeans) were used for multiple comparisons (Tukey-Kramer test) among stations and among depths. Analyses for all taxa and groupings were carried out on $\log_e$(number of cells l^{-1}+1 or number of individuals m^{-3}+1) values. The log transformation best addressed departures from normality and homogeneity and additivity of variance (Sokal and Rohlf 1995; Elliott 1977). The level of significance for all statistical tests was set at $\alpha = 0.05$.

The spatial distribution of benthic macroinvertebrates was analyzed in Microsoft Excel using the distribution fitting feature of the @Risk (Palisade Corp. 2000) version 4 add-in.

Vertical water temperature and dissolved oxygen readings were obtained at plankton station 2 in April, June, August, and December 1996 with a Seabird SBE-25 CTD. Dissolved oxygen values obtained with this instrument were calibrated on each sampling occasion by the Winkler method. Calibration samples were collected with a Knudsen water bottle at the surface, mid-depth, and immediately above the bottom.

RESULTS

WATER TEMPERATURE AND DISSOLVED OXYGEN

Homothermal conditions (2.5°C from surface to bottom) prevailed in late April (Fig. 4). The onset of thermal stratification was evident in early June and was well developed by August. The epilimnion was very shallow in August, extending to a depth of 2 m; surface temperature was 21.9°C. The upper water column cooled considerably by early December as the lake once again approached homothermal conditions. Dissolved Oxygen increased with depth on all sampling occasions (Fig. 4).

NET PHYTOPLANKTON

The results of statistical analyses for the various taxa and groupings of taxa are provided in Table 2 for main effects, Table 3 for multiple comparisons of LSMeans for stations, and Tables 4-7 for multiple comparisons of LSMeans for depths. A complete listing of all taxa found in this study is provided in Appendix 1.

Cyanobacteria

These forms occurred in very low numbers. The most important species was *Schizothrix lacustris* which was found at all stations and all depths except 150, 200, and 250 m in spring and summer of 2003. It was not encountered in 2002. Three other taxa, *Oscillatoria* sp., *Anabaena* sp., and *Merismopedia* sp. made one appearance each.

Chlorophyta

The green algae also occurred in low numbers and were represented mainly by filamentous forms, the most important of which were species of *Mougeotia*. They were present on most sampling occasions at all stations and collectively were found down to a depth of 200 m. Species of *Spirogyra* were also found at all stations (maximum depth of 100 m) but they occurred less frequently. The only other filamentous form encountered was *Microspora* sp. and it made a single appearance. *Gloeocystis vesiculosa* occurred occasionally at all stations (maximum depth of 200 m) and *Dictyosphaerium* sp. was encountered once. The desmids *Arthrodesmus incus*, *Closterium setaceaum*, *Gonatozygon kihnahani*, *Micrasterias thomasiana*, *Spondylosium* sp., *Staurastrum* sp., and *Xanthidium* sp. occurred sporadically in low numbers and all except *A. incus*, which was found down to a depth of 50 m, were confined to depths of ≤ 15 m.

Chrysophyta

Chrysophytes dominated the net phytoplankton and were represented by three species. In order of importance (both abundance and frequency of occurrence) the species were *Dinobryon bavaricum*, *D. sertularia*, and *D. cylindricum*. Seasonally, the number (mean of depths) at peak occurrence for each species at each station in 2003 surpassed that of 2002 being most pronounced overall for *D. cylindricum* (Fig. 5-7). All species were encountered more or less during the same time frame.

There was variability among individual stations for each species with respect to occurrences and absences at various depths (Fig. 8-10), but collectively

throughout the course of the investigation, the means of stations show all depths to be represented (Fig. 11-13). There was a tendency for higher numbers of *D. bavaricum* and *D. sertularia* to be found in the upper water column in July-August (Fig. 11-13) but statistically there was no significant depth effect for any species regardless of season, nor was there a significant station effect (Table 2).

Bacillariophyta

As a group, diatoms followed closely behind chrysophytes in terms of abundance. Three species, in order of importance, *Asterionella formosa*, *Tabellaria fenestrata*, and *T. flocculosa* were common while a few unidentified pennate diatoms were encountered sporadically. The mean at peak occurrence for *A. formosa* at each station in 2003 exceeded that of 2002 (Fig. 14); maxima for stations 1 and 2 in 2003 occurred later than in 2002 while for station 3 timing was similar for both years. The magnitude of maxima for both years for *T. fenestrata* was somewhat similar (Fig. 15). Maxima for stations 1 and 2 (judging from station 2) in 2003 occurred later than in 2002 while for station 3, the reverse was true. In contrast to the other two species, peak numbers of *T. flocculosa* at stations 1 and 3 in 2002 were considerably higher than in 2003 (Fig. 16); abundances for station 2 were somewhat similar for both years. There was no consistent pattern for timing of maxima among stations and years for this species.

While *A. formosa* (Fig. 17) and *T. fenestrata* (Fig. 18) were represented at most depths on various sampling occasions at each station, there was much less consistency for *T. flocculosa* (Fig. 19). With respect to the means of stations, *A. Formosa* and *T. fenestrata* occurred at all depths on all sampling occasions, and while *T. flocculosa* was represented at all depths collectively, it was absent on many sampling occasions (Fig. 20-22).

There was a significant station effect for *T. flocculosa* in summer and autumn of 2002 (Table 2). In both summer and autumn the LSMean for station 3 was significantly higher than that of station 1 and station 3 significantly exceeded station 2 in autumn (Table 3). *Asterionella formosa* and *T. fenestrata* each showed a significant depth effect for summer 2002 (Table 2). LSMeans for *A. formosa* for the 50 and 100 m depths were significantly lower than those of all other depths (Table 4). LSMeans for *T. fenestrata* for the 0, 2, 10, and 15 m depths were significantly higher than for 100 m. There were insufficient data for model calculation for *D. sertularia* in autumn 2002 and *D. bavaricum* and *D. cylindricum* in spring 2003 (Table 2).

Other taxa

The only other forms encountered were two representatives of the Pyrophyta, namely *Peridinium limbatum* and *Ceratium hirundinella*, both of which made a few incidental appearances in low numbers.

Total net phytoplankton

This category predominantly reflects the combined contributions of chrysophytes and diatoms. Again, the mean at peak occurrence for each station in 2003 was higher than in 2002 but the timing of maxima was similar for both years for all stations (Fig. 23). The vertical distribution pattern at the individual station level (Fig. 24) and for the means of stations (Fig. 25) was similar to that depicted above for *A. formosa* and *T. fenestrata*.

There was a significant depth effect for summer 2002 (Table 2). LSMeans for the 0, 2, 5, 10, and 15 m depths were significantly higher than that of the 100 m depth (Table 4).

ZOOPLANKTON

The results of statistical analyses for the various taxa and groupings of taxa are provided in Table 8 for main effects, Table 9 for multiple comparisons of LSMeans for stations, and Tables 10-13 for multiple comparisons of LSMeans for depths. A complete listing of all taxa found in this study is provided in Appendix 2.

Protozoa

The only forms encountered were *Codonella cratera* and one or more species of *Vorticella*. The former made only two appearances in low numbers at Station 2 in 2003, while the latter was found collectively throughout the sampling period in 2003 at all stations and depths. The maximum number of *Vorticella* recorded (15,059 individuals m^{-3}) was for the 100 m depth at station 1 on August 28 followed by 12,235 at the 200 m depth of station 2 on October 1. There was only a single occurrence (471 individuals m^{-3}) in 2002 and this was at the 50 m depth of station 2 on August 8. There were a few instances where *Vorticella* was found epiphytic on *Schizothrix lacustris*.

Rotifera

The most important species were *Kellicottia longispina* and *Pleosoma truncatum*. There was an overall tendency for abundance in 2003 to be somewhat higher than in 2002 for both species (Fig. 26). There was some variation among stations with respect to timing of peak occurrences. However, judging from stations combined, timing was similar in both years for *K. longispina* but the maximum was later in 2003 than in 2002 for *P. truncatum*.

Vertically there was variation in numbers among stations and with sampling time for both species (Fig. 27 and 28). When means of stations are considered, all depths were represented overall (Fig. 29 and 30). There was variation in the occurrence of maxima along the vertical scale for *K. longispina* over time, ranging from 0 to 150 m, but most maxima were confined to 15 m and above (Fig. 29 and 30). Maxima for *P. truncatum* were confined mainly to the upper 10 m of the water column with a few occurrences at 30 m. In contrast to *P. truncatum*, *K. longispina* was not found at the surface on several occasions.

There was a significant station effect in autumn 2002 for *K. longispina* and for the summers of 2002 and 2003 for *P. truncatum* (Table 8). For both species, abundance at station 3 was significantly higher than that of station 1 in all cases (Table 9). There was also a significant depth effect for *P. truncatum* (Table 8); however, the multiple comparisons test failed to detect which depths were involved (Table 13).

Other species encountered on several occasions throughout the investigation were *Asplancha priodonta*, *Conochilus unicornis*, and *Keratella cochlearis*. Maximum numbers reached by these species were 2,118, 1,765, and 941 individuals m^{-3}, respectively. A few appearances in low numbers were made by *Keratella* sp., *Polyarthra* sp. (see later), *Gastropus* sp., *Keratella serrulata*, *K. taurocephala*, *Filinia* sp., *Trichocerca* sp., and *Monostyla* sp. The maximum depths occupied by these species varied with *Conochilus unicornis* and *Keratella* sp. being found down to 100 m, *K. cochlearis* 150 m, *A. priodonta* and *Polyarthra* sp. 200 m, while the remaining species were confined to depths of ≤ 30 m.

Cladocera

The most important forms encountered were the Bosminidae, specifically *Eubosmina longispina* and *Bosmina longirostris*. Under conditions of counting it was not always possible to reliably distinguish these two species and hence they are combined for presentation in Fig. 31-33 (adults plus juveniles). However, a broad-scale observation on the relative importance of each species is possible. Generally speaking, *E. longispina* was the more important of the two, both numerically and in frequency of occurrence by station, depth, and sampling occasion.

There was variation among stations and years in timing of maxima (Fig. 31). Stations 1 and 2 had similar abundances at peak occurrence and there was also similarity between years. Station 3 surpassed stations 1 and 2 in abundance in 2003 but not in 2002; the maximum in 2003 greatly exceed that of 2002 for station 3 and stations combined.

Vertically there was variation in magnitude of abundance and frequency of occurrence among stations and sampling occasions (Fig. 32). With respect to the means of stations however, all depths were represented and this applied to both species (Fig. 33). Depending on the sampling date, vertical maxima occurred between 2 and 50 m of depth but most were confined to the upper 30 m (Fig. 33). On some occasions the maxima were not as well defined as on others. Highest representation at the surface occurred on September 25 and October 29, 2002.

There were significant station effects for the summers of 2002 and 2003 (Table 8). LSMeans for stations 2 and 3 were significantly higher than those of station 1 in both years (Table 9). There was also a significant depth effect for summer 2003 (Table 8) but the multiple comparisons test failed to detect which depths were different (Table 13).

Other cladocerans (adults plus juveniles) encountered on several sampling occasions, but in low numbers (generally < 50 individuals m^{-3}) compared to the Bosminidae, were the larger bodied *Daphnia Catawba* (found down to a depth of 200 m) and *Holopedium gibberum* (down to 150 m). The large predacious *Leptodora kindtii* made two appearances in low numbers (at 50 and 100 m) as did unidentified specimens of Chydoridae (at 2 and 100 m).

Copepoda

Nauplii: It was not possible under conditions of counting to assign nauplii to the various species of copepods encountered, so data presented below are for all species combined (total nauplii). Most however likely belong to *Leptodiaptomus minutus*, the most numerous of the copepods captured. There was variation among stations in the occurrence of maxima and numbers encountered in 2003 were higher than in 2002 (Fig. 34). It is difficult to say if the numbers for July 11, 2002 represent maxima, but judging from 2003 when samples were taken prior to this date, this may indeed be the case. Highest mean abundance occurred at station 3 on July 22, 2003.

There was variation in numbers of individuals at various depths among stations and seasonally (Fig. 35). As a group, nauplii were the most abundant organisms encountered, as exemplified by numbers recorded for July 4, 2003 (Fig. 35). As for the means of stations, it is evident that all depths were represented (Fig. 36).

Vertical maxima occurred at depths ranging from 2 to 30 m depending on the sampling date but most were confined to 2-5 m (Fig. 36). Maxima were not as distinct on some occasions as on others. Overall, nauplii were well represented at the surface.

There were significant station effects for summer 2002 and spring 2003 (Table 8). In both cases LSMeans for station 3 were significantly higher than those of station 1 (Table 9). Significant differences were also found with depth for summers 2002 and 2003 (Table 9). LSMeans for depths ranging from 0 to 15 m were significantly higher than those of 50 and 100 m in 2002 (Table 10) while in 2003 numbers encountered at the 2 and 5 m depths were significantly higher than at 100 and 200 m (Table 13).

Diaptomid copepods: The seasonal distribution of copepodites (stages I-V combined) is shown in Fig. 37. The bulk of these juveniles belong to *Leptodiaptomus minutus*, by far the more numerous of the two diaptomid copepods encountered, the other being *Aglaodiaptomus spatulocrenatus*. Under conditions of counting it was not possible to reliably distinguish juveniles of each species. Timing of maximum abundance among stations was similar in 2002 but in 2003 station 3 differed (earlier) from 1 and 2. Maxima for juveniles in 2002 overall occurred later than those of nauplii (bearing in mind the uncertainty regarding nauplii in 2002 referred to above) while in 2003 timing for both groups was more or less coincident. The highest mean number of juveniles sampled was on July 22, 2003 at station 3.

With respect to vertical distributions, there was a tendency for juveniles to occupy the upper water column but not to the same extent as nauplii; unlike nauplii, substantial numbers were also present in deeper water, particularly in 2003 (Fig. 38). Also, as a group, numerically at peak occurrences juveniles were second only in importance to nauplii. Collectively, all depths were represented (Fig. 39). Over time, vertical maxima occurred between 0 and 100 m but most were present in the upper 15 m of the water column. One interesting observation is the exceptionally high number of juveniles recorded at the 150 m depth on July 22, 2003 (Fig. 39), which correspondingly applied to nauplii (Fig. 36). Juveniles were also reasonably abundant at the surface on most occasions.

There were significant station differences for juveniles in summer 2002 and 2003 (Table 8). In 2002, LSMeans for stations 2 and 3 were significantly higher than that of station 1 (Table 9); in 2003, station 2 exceeded station 1. There were no significant depth effects.

Maxima for adult *Leptodiaptomus minutus* (Fig. 40) tended to occur later than those of juveniles (Fig. 37) in both 2002 and 2003, as expected. Peaks for adults in 2002 were later than in 2003 overall. Numbers of adults recorded in 2003 greatly surpassed those of 2002.

Vertically there was variation in numbers of adult *L. minutus* with depth among stations and sampling occasions (Fig. 41). Vertical maxima for adults occurred at depths ranging from 15 to 100 m, and in contrast to juveniles, most were found at depths from 30 m downwards (Fig. 42). All depths were represented overall. Representation at the surface was not as pronounced as for nauplii and juveniles.

There were significant station effects for *L. minutus* in summer 2002, spring 2003, and summer 2003 (Table 8). LSMeans for stations 2 and 3 were significantly higher than for station 1 in summer 2002 and spring 2003 and station 2 was significantly higher than station 1 in summer 2003 (Table 9). There were also significant depth effects in summer 2002 and 2003 (Table 8). In summer 2002, abundance at 30 m was significantly higher than at 10 m (Table 10). In summer 2003, the depths 15, 30, and 50 m had significantly higher LSMeans than 0, 2, and 5 m and 100 and 150 m were significantly higher than 2 and 5 m (Table 13).

Reference was made above to *Aglaodiaptomus spatulacreantus*. Adults of this species were present rather sporadically on several sampling occasions (most after mid-late summer) in low numbers (generally < 100 individuals m^{-3}; maximum number was 235 at the 150 m depth of station 3 on August 7, 2003) relative to the smaller bodied *L. minutus*. Highest numbers tended to be found at depths between 50 and 250 m.

Other calanoids: The only other species present was the large predacious *Epischura lacustris*. Juveniles of this species were present in low numbers (mainly < 100 individuals m^{-3}; maximum recorded was 212 at the 10 m depth of station 2 on August 7, 2003) from spring through fall. Most juveniles were found at depths of 0-15 m but they also occurred down to 250 m. Adults were present from August onwards and were generally found at densities of < 100 individuals m^{-3}; the maximum number encountered (259) was at the 30 m depth of station 2 on August 27, 2003. Unlike juveniles, most adults were found at depths ≥ 30 m; adults were also found down to 250 m.

Cyclopoid copepods: The seasonal distribution of copepodites (stages I-V combined) is shown in Fig. 43. The timing of occurrence of maxima in the summer was similar for both years but there is also evidence of a second pulse in autumn for 2002. Numbers of juveniles encountered in 2003 were substantially higher than in 2002.

Vertically, there was variation among stations and with season for juveniles (Fig. 44). Vertical maxima occurred at depths between 2 and 150 m but most

tended to be clustered around 10-30 m (Fig. 45). Overall all depths were represented. Presence at the surface was more extensive in 2002 than in 2003.

There was a significant station effect for juveniles in autumn 2002 and spring 2003 (Table 8). The LSMean for station 2 was significantly higher than for station 3 for autumn 2002 but the multiple comparisons test could not detect the differences for spring 2003 (Table 9). There were no significant depth effects.

The only cyclopoid adults identified were *Cyclops scutifer*, so the juveniles referred to above most likely all belonged to this species. While the seasonal pattern for adults overall (judging from stations combined) in 2002 does not reflect the two pulses demonstrated by juveniles (Fig. 43), there is some indication that this might be the case for stations 1 and 2 (Fig. 46). Timing of maxima for adults was more or less coincident with that of juveniles in 2003. Similar to juveniles, densities of adults in 2003 were substantially higher than in 2002.

Vertical maxima for adults were found at depths ranging from 2 to 250 m, but most were present at ≥ 30 m; collectively throughout the course of the investigation all depths were represented (Fig. 47 and 48). Substantial numbers were found at 150 and 250 m in 2003. Compared to juveniles, adults were not that well represented at the surface.

There were no significant station effects for adults but there were differences with depth for summer 2002 and 2003 (Table 8). In 2002, LSMeans for 30 and 50 m were significantly higher than all other depths (Table 10). In 2003, the LSMeans for 30 and 50 m (significantly different from each other) were significantly higher than those of shallower depths, and 150 m exceeded 0-10 m as did 100 and 200 m relative to 5 m (Table 13).

Other taxa

Harpacticoida (Copepoda) were present on two occasions (maximum number = 941 individuals m^{-3}; maximum depth = 10 m). Ostracoda were also encountered twice (maximum number = 353; maximum depth = 150). Representives of the Hydracarina made several appearances (maximum number = 588; maximum depth = 150).

Major groups

Total Rotifera: Seasonal distributions of rotifers as a group (Fig. 49) reflect the combined numerical dominance of *Pleosoma truncatum* and *Kellicottia longispina*. Judging from data for stations combined, the tendency for abundance in 2002 to be somewhat higher than in 2003 reported above for these

two species is lost when considering the group as a whole (here both years are similar). There was some variation among stations with respect to timing of peak occurrences. The peak for 2002 occurred later than in 2003 for stations combined. As was the case when considering separate species, there was variation in numbers with depth among stations and with sampling time (Fig. 50) and the combined effects of the dominant species are reflected when means of stations are considered (Fig. 51).

There were significant station effects for summer and autumn of 2002 (Table 8). For the former, the LSMean for station 3 was significantly higher than that of station 1 and for the latter station 2 exceeded station 1 (Table 9). There were no significant depth effects.

Total Cladocera, total Copepoda, and total microcrustacea: Seasonal distributions of total Cladocera and total Copepoda (exclusive of nauplii) are shown in Fig. 52. The numerical dominance of copepods is quite evident. Maximum numbers of cladocerans preceded those of copepods at all stations in 2002 while in 2003 there was variability in timing among stations (for stations combined peaks coincided). Vertical distributions for stations separately (Fig. 53) and the means of stations (Fig. 54) for total Cladocera reflected the strong influence of Bosminidae. The same can be said for the influence of diaptomids on vertical distributions of total Copepoda (Fig. 55 and 56).

With respect to station and depth effects, the pattern of statistical differences identified for total Cladocera was the same as presented above for Bosminidae (Table 8). There were differences however between total Copepoda and the dominating diaptomids. In contrast to diaptomids, all four seasons showed significant station effects for total Copepoda (Table 8). In summer 2002 and spring 2003, LSMeans for stations 2 and 3 were significantly higher than for station 1; in autumn 2002 and summer 2003 station 2 was higher than station 1 (Table 9). There were no significant depth effects.

Observations pertaining to total Copepoda more or less apply to the microcrustacea (nauplii excluded) as a group (Fig. 57-59). There were significant station effects for summer 2002 and spring and summer 2003 (Table 8). In summer 2002 and spring 2003, numbers for stations 2 and 3 were significantly higher than for station 1 while in summer 2003 station 2 was higher than station 1 (Table 9). There was also a significant depth effect for spring 2003 (Table 8); numbers at 15 and 100 m were significantly higher than at 10 m (Table 12).

Total zooplankton: Nauplii (Fig. 34-36) strongly influenced the distributional patterns of total zooplankton (Fig. 60-61) during times of high abundance. As noted above, this is particularly evident comparing the results for the 150 m

depth (Fig. 36 versus Fig. 62) on July 22, 2003. Substantial numbers of zooplankton were present in deeper water.

There were significant station effects but no depth effects for total zooplankton (Table 8). LSMeans for stations 2 and 3 were significantly higher than station 1 in summer 2002 and station 2 was higher than station 1 in autumn 2002.

BENTHIC MACROINVERTEBRATES

Main body of lake

Petersen grab sampling resulted in the capture of only a single taxon, namely Chironomidae. These organisms were present in all but two samples (stations 7 and 30). The average density was 123 individuals m^{-2} and the maximum number encountered was 506. The frequency distribution (Fig. 63) was best described by a negative binomial (Chi sq. = 3.495; P = 0.6241). Of the total of 335 individuals captured, 11 (3.3%) were unsuiTable for taxonomic purposes. Those identified all belonged to the genus *Sergentia* (Subfamily Chironominae), possibly more than one species.

Chironomids were also present in 11 out of the 17 qualitative sled samples (they were absent from stations 2, 5, 9, 13, 14, and 17). *Sergentia* was the only form found in nine of the 12 stations, while a single genus also occurred at each of stations 6, 7, and 12 namely, *Procladius* (Tanypodinae), *Protanypus* (Diamesinae), and *Paracladopelma* (Chironominae), respectively. Representatives of the Oligochaeta were also encountered at stations 5 and 7. All specimens but one were immature and hence could only be identified reliably to the family level, in this case the Lumbriculidae. The single mature specimen was identified as *Stylodrilus heringianus* and was found at station 7.

Joe's Feeder

Petersen grab samples yielded specimens of Chironomidae in only three (1, 4, and 10) of the ten stations sampled and they were all *Sergentia*. Mean density was 11 individuals m^{-2} (variance = 335; maximum = 43). Oligochaetes were also present at stations 1 and 4. Again, immature specimens were involved and identification was only possible to the family level, which in this case turned out to be Tubificidae. Densities encountered were 22 at station 1 and 66 at station 4. Empty shells of *Valvata sincera* (Gastropoda: Valvatidae) were also found at station 1 (44 individuals m^{-2}).

DISCUSSION

PLANKTON

The topic of spatial and temporal heterogeneity in freshwater plankton populations and questions related to representative sampling and the application of appropriate statistical and modeling procedures has received much attention (e.g., Patalas 1969, 1981; Allen 1977; Harris 1980; Tilman et al. 1982; Malone and McQueen 1983; Wetzel 1983; Blouin et al. 1984; Holmgren 1984; O'Connell and Andrews 1987; Schindler 1987; Pace et al. 1991; Pinel-Alloul and Pont 1991; Knoechel and Campbell 1992; Patalas and Salki 1992, 1993; Cloern et al. 1992; Arnott et al. 1998; Attayde and Bozelli 1998; Folt and Burns 1999; Pinel-Alloul et al. 1999; Klausmeier and Litchman 2001; Masson et al. 2004). It should be reiterated that the sampling regime for the Gander Lake plankton study was not based on an *a priori* design but was tailored in response to findings of an examination of the feeding ecology and trophic relationships of Arctic charr. Temporally, there was some duplication or correspondence of sampling times between the two years for the summer months but this did not apply to spring and autumn. However, while remaining cognizant of the influence of potential temporal heterogeneity, a composite representation of the entire spring through autumn period is possible using a combination of the two years. Horizontal heterogeneity in the offshore open-water areas of the lake was addressed to some degree by sampling three stations. Patalas (1993) concluded that a single station was not sufficient to characterize average plankton populations in larger lakes. The lack of consistency over time in depths sampled along the vertical plane is problematic, not only with respect to gaps in information, but also in terms of application of suiTable statistical analysis procedures. With respect to the latter, while the partitioning of information into discrete data sets by season allowed for more uniformity of depths and hence contributed to more balanced designs, it eliminated formal statistical comparisons along the temporal scale, and hence permitted only qualitative statements regarding the differences in abundance observed between the two years for many taxa. Another element of vertical sampling that warrants mention pertains to the depths chosen. Other choices of sampling depths might have produced differences from or variations on the results currently reported.

Collectively, substantial numbers of the various phytoplankters were found in very deep water in Gander Lake (some more so than others), well below the euphotic zone. There was no attempt here to ascertain the physical condition of phytoplankton cells (healthy versus moribund or dead). Substantial numbers of zooplankters were also present throughout the water column and at the extreme depths sampled. Horizontally, the abundances of most zooplankton taxa and groupings at station 1 were consistently the lowest of the three and statistically so in most cases. The present exercise is limited to documenting the horizontal and vertical occurrences of the various phytoplankton and zooplankton taxa and

as such there will be no attempt to explore possible mechanisms producing the observed patterns at this stage.

The good representation at most depths for nearly all taxa facilitated the use of mean abundance of all depths in the presentation of results and for comparisons with other studies, the results of statistical analyses notwithstanding.

Net phytoplankton

All taxa found in Gander Lake except *Schizothrix lacustris* have been previously reported for Newfoundland (refer studies cited above). It was mentioned earlier that the phytoplankters retained in the 63 µm mesh of the plankton trap drain represent only a portion of the total taxa present. The capture of smaller organisms (ultraphytoplankton and nanophytoplankton) would have necessitated the use of a sedimentation technique (Utermohl 1958). Most of the phytoplankton studies cited in the Introduction were based on sedimentation, but some (Davis 1972a, 1973; O'Connell and Andrews 1987) used both the sedimentation and net methods, permitting comparisons of findings reported for net phytoplankton with those of Gander Lake. These are seasonal, quantitative studies. The net aperture size used by Davis (1972a, 1973) was 55 µm and that of O'Connell and Andrews (1987) was 64 µm. A major difference to be kept in mind however is compared to Gander Lake, the water bodies (all on the Avalon Peninsula) in these studies are small (largest has a surface area of 129.9 ha) and shallow (the deepest = 12.2 m). Also, the ponds in the O'Connell and Andrews (1987) study are prone to rapid flushing rates which can have a significant impact on numbers and species composition of phytoplankton (Dickman 1969; O'Connell and Andrews 1977).

For the most part, maxima for *Asterionella formosa*, *Tabellaria fenestrata*, *T. flocculosa*, *Dinobryon bavaricum*, and *D. sertularia* in Davis (1972a, 1973) and O'Connell and Andrews (1987) occurred in April through July. This compares to mainly August for Gander Lake (means of depths). Davis (1972) reported an average abundance of *A. formosa* at peak occurrence for Hogans Pond in the order of 220,000 cells l^{-1} and for Bauline Long Pond (Davis 1973) a value of 49,000 was provided, numbers far exceeding those observed for Gander Lake. Average abundance (and also looking at individual depths in the upper 15 m of the water column) of this species in Gander Lake is more or less comparable to that reported for three of the four ponds in O'Connell and Andrews (1987). The exception is Sampsons Pond, which received inputs of air-borne phosphorus from an electric reduction phosphorus plant, where the maximum abundance achieved was 6,300,000 cells l^{-1}. Davis (1972a) reported a peak occurrence of *T. fenestrata* numbering 75,000 cells l^{-1} for Hogans Pond, again far in excess of numbers in Gander Lake, while this species was relatively unimportant in Bauline Long Pond (Davis 1973). Abundance in Gander Lake was within the range of maximum numbers encountered in the four ponds of the O'Connell and Andrews

(1987) study (300-9700 cells l^{-1}). Numbers of *T. flocculosa* in Gander Lake were comparable to those of the other ponds. Except for Bauline Long Pond (Davis 1973), where a maximum of 243,000 cells l^{-1} was encountered, the abundance of *D. bavaricum* in Gander Lake and the remaining ponds was more or less similar. There was also similarity between Gander Lake and the other studies in the abundance of *D. setularia* and *D. cylindricum*, but the occurrence of the latter species was limited to two of the four ponds examined by O'Connell and Andrews (1987).

A noticeable difference between Gander Lake and the four ponds in O'Connell and Andrews (1987) was the great discrepancy in the abundance of desmids. Although occurrences were sporadic both in Gander Lake and in these four ponds, only seven taxa were encountered for the former compared to 79 in total for the latter. Similar to Gander Lake, desmids were relatively unimportant in Hogans Pond (Davis 1972a) and Bauline Long Pond (Davis 1973).

Zooplankton

All taxa found in Gander Lake have been previously reported for Newfoundland (in the various publications cited above). A good idea of the geographical distributions of rotifers and microcrustaceans and their frequencies of occurrence can be obtained from Scruton et al. (1991) who surveyed 108 lakes spread throughout Newfoundland. Each lake was sampled on a single occasion. They also incorporated information available from the literature up to that point.

A previous study of particular relevance to Gander Lake is that of Ryan (1982) who conducted a seasonal, quantitative study of the zooplankton of three ponds located near the headwaters of Northwest Gander River, a major tributary flowing into the southwestern corner of Gander Lake (Fig. 1). These ponds (Spruce Pond: area = 36.5 ha, maximum depth = 2.1 m; Headwater Pond: area = 76.1 ha, maximum depth = 3.3 m; Little Gull Lake: area = 306.5 ha, maximum depth = 6.3 m) are small and shallow. From a species composition standpoint and for the three ponds combined, the only protozoans reported by Ryan (1982) were unidentified members of the amoeboid family Testacida. By comparison, those occurring in Gander Lake were ciliates, *Codonella cratera* and *Vorticella* sp. (some of the latter were epiphytic on *Schizothrix lacustris*). Davis (1972a) reported the occurrence of *Actinospharium* sp. in Hogans Pond and a species of *Vorticella* that was present almost exclusively as epiphytic on the blue-green alga *Anabaena flos-aquae*. *Vorticella* was also epiphytic on *A. flos-aquae* and epizoic on *Conochilus unicornis* in Bauline Long Pond (Davis (1973); other forms reported for this pond include *Epistylis rotans*, *C. cratera*, and *Actinospharium* sp. O'Connell and Andrews (1987) found symbiotic relationships between *Vorticella* sp. and *A. flos-aquae* and between *Epistylis* sp. and *Leptodiaptomus minutus* for their ponds; other forms encountered include *C. cratera*, *E. rotans*, *Tintinnopsis* sp., and *Actinospharium* sp.

Davis (1972a, 1973) found 12 species/genera of rotifers in Hogans Pond and 13 in Bauline Long Pond while O'Connell and Andrews (1987) reported a range of 14-23 for their four ponds. Ryan (1982) found 16 species in his ponds which compares to 13 for Gander Lake. Of these, eight (*Kellicottia longispina*, *Pleosoma truncatum*, *Keratella cochlearis*, *K. serrulata*, *K. taurocephala*, *Polyarthra* sp., *Asplancha priodonta*, and *Conochilus unicornis*) were common to the three ponds and Gander Lake. With respect to *Polyarthra*, owing to the small number of Gander Lake specimens available and their condition, it was not possible to reliably ascertain the species involved. The species designated for the three ponds was *dolichoptera*, which could also apply to Gander Lake. Species found in Gander Lake but not in the three ponds include *Gastropus* sp., *Filinia* sp., *Trichocerca* sp., and *Monostyla* sp. For the reverse situation, the species include *Bipalpus hudsoni*, *Synchaeta pectinata*, *Brachionus quadridentatus*, *Keratella crassa*, *Lecane luna*, *Euchlanis dilatata*, *Euchlanis* sp., and *Trichocerca platessa*. Depending on the pond and sampling date, *C. unicornis*, *K. longispina*, and species of *Keratella* were reported as being most abundant by Ryan (1982). By comparison, only *K. longispina* and *P. truncatum* achieved any significance in Gander Lake; the latter species was of only minor consequence in the three ponds. Elsewhere, Davis (1972a) reported *C. unicornis*, *K. longispina*, and *K. cochlearis* to be the most abundant rotifers in Hogans Pond and the same was more or less true for Bauline Long Pond (Davis 1973) where additionally *Polyarthra vulgaris* was an important species. These species (substitute *Polyarthra dolichoptera* for *P. vulgaris*) were also listed as being the most abundant in the four ponds of the O'Connell and Andrews (1987) study; noTable numbers were also achieved by *Kellicottia bostoniensis*, *P. truncatum*, *Synchaeta* sp., and *Trichocerca* sp. Comparisons of species composition and abundance among these studies might be complicated by the fact that there was variation in the aperture size of plankton nets used. The aperture sizes for Davis (1972a, 1973) and O'Connell and Andrews (1987) were presented above in connection with net phytoplankton studies; Ryan (1982) and Scruton et al. (1991) used 64 µm. Likens and Gilbert (1970) recommend an aperture size of 35 µm in order to capture smaller individuals.

Davis (1972a, 1973) reported six species of planktonic microcrustacea in Hogans Pond and eight in Bauline Long Pond; O'Connell and Andrews (1987) found a range of 14-23 species. Ryan (1982) listed 15 planktonic species compared to nine for Gander Lake. Cladoceran species common to Ryan's ponds and Gander Lake were *Bosmina longirostris*, *Holopedium gibberum*, *Daphnia catawba*, and *Leptodora kindtii*. A noTable difference is that Ryan (1982) found only a single bosminid species, *B. longirostris*, while in Gander Lake there were two, *B. longirostris* and *Eubosmina longispina*. These two species combined were the numerically dominant cladocerans in Gander Lake and similarly *B. longispina* dominated in the three ponds. In their examination of 108 lakes in Newfoundland, Scruton et al. (1991) reported the co-occurrence of *E. longispina* and *B. longirostris* in only 12 cases. Cladocerans reported by Ryan (1982) that

were not found in Gander Lake include *Latona setifera*, *Sida crystallina*, *Diaphanosoma brachyurum*, *Simocephalus vetulus*, and *Polyphemus pediculus*. Ryan (1982) also listed 12 species of Chydoridae whereas in Gander Lake only a few unidentified specimens were encountered. These forms are mainly littoral or benthic and presence in the plankton of the three ponds was likely a function of the shallow depths of the ponds. In the only other study of a large lake in Newfoundland, Morry and Cole (1977) found *B. longirostris* to be the most common and abundant species in Red Indian Lake with *H. gibberum* and *D. catawba* being of minor significance, similar to the situation for Gander lake. Other species listed for Red Indian Lake were *L. setifera*, *L. Kindtii*, *S. crystallina*, and *Chydorus sphaericus*. *H. gibberum*, *D. catawba*, and *E. longispina* were all important species in Hogans Pond (Davis 1972a) and Bauline Long Pond (Davis 1973). These were also the most abundant species found by O'Connell and Andrews (1987) but here *D. catawba* was of less importance; other species reported were collectively *L. kindtii*, *D. brachyurum*, *Latona parviremis*, *Daphnia dubia*, *D. longiremis*, *Ceriodaphnia* sp., *Ophryoxus gracilis*, *P. pediculus*, and unidentified chydorids. Compared to elsewhere in Newfoundland, it is obvious the diversity of cladoceran species in Gander Lake is quite low, and in particular the large bodied forms are lacking.

The three calanoid copepods found in Gander Lake were also the only species reported by Ryan (1982), and in both studies, *Leptodiaptomus minutus* was the most important in terms of abundance. Calanoid species found in Red Indian Lake (Morry and Cole 1977) were *L. minutus*, *E. lacustris*, and *Onychodiaptomus sanguineus*, the first of which was the most important. Of all studies of crustacean zooplankton in Newfoundland, this is the only one that reports the presence of *Onychodiaptomus sanguineus*, a species which very closely resembles the relatively widely distributed *Aglaodiaptomus spatulacreantus*. In this context it is possible the identification for Red Indian Lake is in error. *L. minutus* was also the dominant form reported by Davis (1972a, 1973) and O'Connell and Andrews (1987). *Epischura lacustris* was not reported by Davis (1972a, 1973) and was found only in two of the ponds in O'Connell and Andrews (1987), where it was of minor significance. The large predacious *Epischura nordenskiöldii*, which was not found in Gander Lake, was an important species in all three of the latter studies.

The only cyclopoid copepod found in Gander Lake was *Cyclops scutifer*; this species was not present in the three ponds of Ryan (1982). The latter study however reported the presence of three other cyclopoid species, *Mesocyclops edax*, *Acanthocyclops vernalis*, and *Eucyclops agilis*, of which *M. edax* was the dominant form. *Cyclops scutifer* was fairly common in Red Indian Lake (Morry and Cole 1977) and there were a few appearances by *Acanthocyclops vernalis*. The former species was also an important constituent in the studies by Davis (1972a, 1973) but not so for O'Connell and Andrews (1987). *Cyclops scutifer* has been described as a hypolimnetic species (Pennak 1989) but in

Newfoundland it occupies both shallow (weakly or transiently stratified) and deep lakes.

With respect to some deep lakes elsewhere in North America, McLaren (1964) reported the planktonic crustacean zooplankton community in the oligotrophic high Arctic Lake Hazen, Ellesmere Island, to consist almost entirely of *Cyclops scutifer* with a few occurrences by *Daphnia middendorffiana*. Johnson (1975) found only five species of microcrustacea in oligotrophic Great Bear Lake, Northwest Territories, Canada, consisting of four copepod species and a single cladoceran. At the other extreme, Barbiero et al. (2001) reported a total of 35 taxa collectively for the open waters of the Great Lakes. All lakes were similar in species composition except Lake Erie which had the most species-rich community.

Similar to Gander Lake, copepods dominated the microcrustacea in the studies by Davis (1972a, 1973) and Ryan (1982). This also applied to two of the ponds in the O'Connell and Andrews (1987) study, while for the remaining two, cladocerans were the most abundant. Where copepods were dominant, the most important species in all cases was *Leptodiaptomus minutus*. Average numbers of this species at peak abundance (adults and juveniles combined) in the order of 27,000 individuals m^{-3} were recorded for Hogans Pond (Davis 1972a), 50,000 for Bauline Long Pond, 16,000-18,600 for the Ryan (1982) ponds, and 16,000-17,000 for the two ponds in O'Connell and Andrews (1987). This compares to 4,800 averaged over all stations and all depths in Gander Lake. In consideration of the shallow depths of the ponds cited above, the average down to 15 m in Gander Lake was 5,700, not that different than when all depths are included. For the two ponds in O'Connell and Andrews (1987) where cladocerans (comparisons here and elsewhere are for adults and juveniles combined) dominated the microcrustacea, the dominant species in one was *Eubosmina longispina* (number at peak occurrence was 33,400 individuals m^{-3}) and in the other it was *Holopedium gibberum* (maximum number = 16,200). Maximum numbers of *E. longispina* recorded for Hogans Pond (Davis 1972a), Bauline Long Pond (Davis 1973), and the ponds of Ryan (1982) were 8,900, 3,600, and 4,300-5,300, respectively. In Gander Lake, the average number of Bosminidae over all stations and all depths was 400 which compares to 585 when only depths down to 15 m are considered. Although *Daphnia catawba* and *H. gibberum* were of relatively little importance in Gander Lake and the ponds of Ryan (1982), they achieved significant numbers in the Davis (1972a, 1973) studies. *D. catawba* peaked at 3,800 in Hogans Pond and 5,800 in Bauline Long Pond; numbers for *H. gibberum* were 3,000 and 3,600. Cladocerans were also dominant in Long Pond, St. John's, Newfoundland, which is a polluted pond in an urban setting (O'Connell and Andrews 1977), and here *E. longispina* and *D. catawba* were of similar abundance (83,000). In the Long Pond study, *E. longispina* was referred to as *Bosmina coregoni*, based on the erroneous designation in the key by Brooks (1959).

Davis (1976) reported maximum mean abundances of total microcrustacea (exclusive of nauplii) in Bauline Long Pond and Hogans Pond to be 40,000 and 47,000 individuals m^{-3}. Ryan (1982) reported a range (nauplii excluded) of 18,000-25,000 for his ponds while those of O'Connell and Andrews (1987) varied between 22,000 and 43,000. In vertical tows from 40 m and 350 m, Johnson (1975) obtained densities (with only minor representation by nauplii) of around 100 and 3500 in summer in Great Bear Lake. In a study of nine Canadian Shield lakes in Northwestern Ontario (which included Lake Superior), Patalas and Salki (1993) found average abundances of microcrustaceans (nauplii deducted based on percent composition information presented in that paper) between 5,000 (Lake Superior) and 28,000 (Green Lake). The smaller lakes were sampled with vertical tows from just above the bottom to the surface while Lake Superior was sampled from 50 m to the surface. Using similar sampling methodology to that employed by Patalas and Salki (1993) for Lake Superior, Watson and Carpenter (1974) found average abundances of total microcrustacea in Lake Erie, Lake Ontario, and Lake Huron to be 204,037, 55,000, and 20,780, respectively. In a more recent Great Lakes study, Barbiero et al. (2001) reported an average summer density of 3,571 for Lake Superior, 6,772 for Lake Michigan, 12,100 for Lake Huron, 21,827 for western Lake Erie, and 27,284 for Lake Ontario, based on vertical tows from as deep as 100 m. Because of lower densities of organisms in deeper water, these authors point out that presentation of abundance estimates from integrated tows in terms of volumetric units presents a negative bias. As can be seen from Fig. 59, this situation does not apply to Gander Lake where there is good representation in deep water. In comparison to the above studies, the average over all stations and all depths for Gander Lake was 5,400 and down to 15 m it was 6,200. Also, the long history of ecological impacts induced by human activity (Francis et al. 1979; Bronte et al. 2003; Mills et al. 2005) should be taken into account when making comparisons involving the Great Lakes.

In the ponds studied by O'Connell and Andrews (1987), protozoans and rotifers contributed the bulk of organisms (numerically speaking) to the total zooplankton grouping. These forms were also the most numerous in the Davis (1972a, 1973) and Ryan (1982) studies. In Gander Lake on the other hand, copepod nauplii were the most important constituents of total zooplankton during times of peak abundance. It should be emphasized that protozoans and rotifers are small in size compared to microcrustacea other than nauplii and that in terms of biomass microcrustacea are of much greater importance. As mentioned earlier in relation to net phytoplankton, the O'Connell and Andrews (1987) ponds are subject to high flushing rates. As with phytoplankton, this situation can variously affect numbers and species composition of the zooplankton (Brook and Woodward 1956; O'Connell and Andrews 1977) and should be kept in mind when studies are compared.

Diel or diurnal vertical migration (DVM) of zooplankton has long been observed, and explanations for such behavior and its adaptive significance continues to be

the subject of much debate (e.g. Hutchinson 1967; Stich and Lampert 1981; Wetzel 1983; Lampert 1989; Loose and Dawidowicz 1994; Ghan et al. 1998a, 1998b; Barbiero et al. 2000; Hays 2003; Winder et al. 2003; Wissel and Ramacharan 2003; Boeing et al. 2004; Kessler and Lampert 2004). For a given species there can be considerable variation within and among lakes with respect to DVM and behavior can differ with sex and life stage of the same species. In the broad sense, DVM involves the upward movement of organisms into shallow water at night and descent into deeper water during the day. The reverse has also been observed. Samples were taken in Gander Lake corresponding to times when, according to the literature, migration into deeper water should have occurred. For the zooplankton species found in the current investigation, there is no information in the literature on vertical distribution down to the maximum depth studied in Gander Lake. Barbiero et al. (2005) studied the vertical distribution of zooplankton in Lake Michigan (maximum depth = 282 m, similar to Gander Lake) on a single occasion in August using integrated vertical tows with a metered closing net, at 20 m intervals from the surface down to 100 m. They found *Bosmina longirostris* to be concentrated in the upper 20 m during the night while during daytime most were found at 20-40 m with little representation above and below this interval. The daytime distribution is somewhat similar to that observed for Gander Lake in August 2002, but contrasts with August 2003 when substantial numbers were observed above and below the interval in question. Barbiero et al. (2005) also found *Leptodiaptomus minutus* to predominantly occupy the 0-20 m interval at night, and during the day, while substantial numbers migrated into the 20-40 m stratum the upper 20 m was still well represented. The population below 20-40 m however was relatively minor during day and night. The daytime pattern is in contrast to Gander Lake for August of both years where the upper depths of the water column were not as populated as the deeper water. Adult *Epischura lacustris* had night and day vertical distributions similar to *Bosmina longirostris* in Lake Michigan. In Gander Lake most were found at depths ≥ 30 m. *Epischura* copepodites were concentrated mainly in the upper 20 m of the water column in Lake Michigan during night and day; similarly, most were found in Gander Lake in the upper 15 m. Any comparisons between Gander Lake and Lake Michigan should obviously take into account major differences between the two particularly with respect to trophic status and species composition of zooplankton and fish. Gander Lake is relatively pristine with sparse zooplankton and fish faunas. Lake Michigan on the other hand has a much more diverse zooplankton and fish species composition and has been subject to considerable cultural pertubations (including introductions of exotic fish and invertebrate predators on zooplankton) over the years with various impacts on zooplankton populations (Barbiero et al. 2005).

BENTHIC MACROINVERTEBRATES

Spatial patterns of benthic macroinvertebrates described by a negative binomial distribution, such as obtained for the main body of Gander Lake, are clumped or

contagious (Elliott 1977). Based on criteria in Elliott (1977), sampling intensity in the main body of the lake was sufficient but the Joe's Feeder area could have benefited from more samples.

With only five taxa encountered overall and in very low numbers, Morry and Cole (1977) described the benthos of Red Indian Lake as depauperate and this not only applied to areas impacted by mine tailings but to un-impacted areas as well. Only oligocheates (*Rhyacodrilus*) and unidentified chironomids were found at profundal depths beyond 27 m, a result very similar to that observed for Gander Lake. Abundance and diversity in Gander Lake are low compared to reports for profundal areas of deep, oligotrophic Great Slave Lake, Northwest Territories (Rawson 1953), Lake Huron (Teter 1960), Lake Michigan (Robertson and Alley 1966; Nalepa et al. 1998), and Lake Superior (Cook 1975).

A comparison of particular relevance to Gander Lake is with Loch Ness, Scotland. This lake (surface area = 5,700 ha; maximum depth = 230 m) is also long, narrow and deep with steep sides and is described as oligotrophic, with water high in colored humic material (George and Winfield 2000). In a survey of profundal invertebrates at depths > 200 m, Martin and Shine (1993) reported the presence of a total of 64 species/genera for Loch Ness. This compares to only five identified for Gander Lake. Sampling devices employed in Loch Ness were more varied than in Gander Lake and samples were sifted through finer sieves in the former which could account for some of the difference. Also, an Ekman grab was used for quantitative sampling in Loch Ness while in Gander Lake it was a Petersen grab, hence there may have been some differences in sampling efficiency. Although the Petersen grab is designed more for harder than soft substrates, great care was taken in lowering the device into place in Gander Lake in order to minimize disturbance of the superficial layers of sediment and to prevent undue penetration.

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Table 1. Morphometry of Gander Lake.

Parameter	Value
Surface area (ha)	11,320
Volume (m^3)	119.266×10^8
Maximum length (km)	51.6
Maximum width (km)	5.6
Mean width (km)	2.2
Maximum depth (m)	288
Mean depth (m)	105.4

Table 2. Results of GLM analyses for the more important net phytoplankton taxa and total net phytoplankton.

Taxon/Grouping		Model				Station				Depth (m)			
		Summer/02	Autumn/02	Spring/03	Summer/03	Summer/02	Autumn/02	Spring/03	Summer/03	Summer/02	Autumn/02	Spring/03	Summer/03
		df = 9, 95	df = 9, 54	df = 9, 62	df = 12, 84	df = 2	df = 2	df = 2	df = 2	df = 7	df = 7	df = 7	df = 10
Chrysophyta													
Dinobryon bavaricum	F	1.39	1.08		0.36	0.21	0.44		0.43	1.72	1.26		0.35
	P	0.2055	0.3933		0.9731	0.8094	0.6482		0.6545	0.1132	0.2864		0.9643
Dinobryon sertularia	F	1.15		1.00	0.88	0.55		1.00	2.27	1.32		1.00	0.60
	P	0.3366		0.4497	0.5667	0.5793		0.3737	0.1095	0.249		0.44	0.8092
Dinobryon cylindricum	F	1.15	0.96		1.19	1.42	0.83		2.82	1.07	0.99		0.84
	P	0.3379	0.4851		0.3030	0.2470	0.4423		0.0654	0.3890	0.4457		0.5879
Bacillariophyta													
Asterionella formosa	F	3.22	0.38	1.20	0.59	1.43	0.44	0.93	0.09	3.73	0.37	1.28	0.70
	P	0.0019	0.9388	0.3104	0.8421	0.2444	0.6475	0.3990	0.9177	0.0013	0.9181	0.2758	0.7235
Tabellaria fenestrata	F	2.63	1.22	0.37	1.42	1.49	1.97	0.29	0.31	2.96	1.01	0.39	1.64
	P	0.0091	0.3027	0.9452	0.1744	0.2299	0.1498	0.7489	0.7309	0.0075	0.4374	0.9033	0.1087
Tabellaria flocculosa	F	2.46	1.52	1.14	1.23	6.50	3.12	1.98	2.32	1.30	1.06	0.90	0.93
	P	0.0145	0.1645	0.352	0.2788	0.0023	0.0521	0.147	0.1048	0.2569	0.4000	0.5159	0.5068
Total net phytoplankton[A]	F	3.67	0.70	0.99	0.54	2.10	1.87	1.03	0.44	4.12	0.37	0.98	0.56
	P	0.0006	0.7026	0.4562	0.8858	0.1281	0.1633	0.3638	0.6468	0.0005	0.9162	0.453	0.8391

[A]Total also includes taxa not listed in table.

Table 3. Results of multiple comparisons testing for stations for the more important net phytoplankton taxa and total net phytoplankton. The superscript associated with each LSMean denotes the station and the subscript refers to a station or stations from which it differs significantly ($P < 0.05$).

Taxon/Grouping	LSMeans (descending order)											
	Summer/02			Autumn/02			Spring/03			Summer/03		
Chrysophyta												
Dinobryon bavaricum	$^{1}2.45$	$^{2}2.31$	$^{3}2.12$	$^{2}0.29$	$^{1}0.16$	$^{3}0.12$				$^{3}4.07$	$^{2}3.88$	$^{1}3.38$
Dinobryon sertularia	$^{3}1.88$	$^{2}1.45$	$^{1}1.36$				$^{1}0.18$	$^{3}0.00$	$^{2}0.00$	$^{3}4.03$	$^{2}3.24$	$^{1}2.50$
Dinobryon cylindricum	$^{1}0.44$	$^{2}0.21$	$^{3}0.08$	$^{2}0.07$	$^{3}0.00$	$^{1}0.00$				$^{2}2.63$	$^{3}1.93$	$^{1}1.41$
Bacillariophyta												
Asterionella formosa	$^{3}5.17$	$^{1}4.83$	$^{2}4.82$	$^{3}4.26$	$^{1}4.10$	$^{2}4.01$	$^{2}3.53$	$^{3}3.40$	$^{1}3.23$	$^{3}6.29$	$^{2}6.17$	$^{1}6.12$
Tabellaria fenestrata	$^{3}4.84$	$^{2}4.76$	$^{1}4.43$	$^{3}4.93$	$^{2}4.50$	$^{1}4.45$	$^{2}3.05$	$^{3}2.98$	$^{1}2.81$	$^{3}5.15$	$^{2}5.11$	$^{1}4.89$
Tabellaria flocculosa	$^{3}2.12_{(1)}$	$^{2}1.68$	$^{1}0.88$	$^{3}0.66_{(1,2)}$	$^{1}0.25$	$^{2}0.11$	$^{1}0.16$	$^{3}0.00$	$^{2}0.00$	$^{2}1.52$	$^{3}1.38$	$^{1}0.85$
Total net phytoplankton[A]	$^{3}6.07$	$^{2}5.78$	$^{1}5.61$	$^{3}5.45$	$^{1}5.14$	$^{2}5.10$	$^{2}4.17$	$^{3}4.03$	$^{1}3.86$	$^{3}7.12$	$^{2}6.86$	$^{1}6.70$

[A]Total also includes taxa not listed in table.

Table 4. Results of multiple comparisons testing for depths for the more important net phytoplankton taxa and total net phytoplankton, summer 2002. The superscript associated with each LSMean denotes the depth and the subscript refers to a depth or depths from which it differs significantly ($P < 0.05$).

Taxon/Grouping	LSMeans (descending order)							
Chrysophyta								
Dinobryon bavaricum	$^{0}3.11$	$^{10}2.96$	$^{5}2.86$	$^{15}2.85$	$^{2}2.74$	$^{50}1.50$	$^{30}1.32$	$^{100}1.00$
Dinobryon sertularia	$^{5}2.30$	$^{10}2.29$	$^{0}2.22$	$^{2}2.04$	$^{50}1.34$	$^{15}1.25$	$^{30}1.03$	$^{100}0.00$
Dinobryon cylindricum	$^{10}0.71$	$^{15}0.40$	$^{2}0.37$	$^{5}0.34$	$^{30}0.14$	$^{100}0.00$	$^{50}0.00$	$^{0}0.00$
Bacillariophyta								
Asterionella formosa	$^{0}5.69_{(50,100)}$	$^{2}5.38_{(50,100)}$	$^{5}5.37_{(50,100)}$	$^{15}5.19_{(50,100)}$	$^{10}5.05_{(50,100)}$	$^{30}4.64_{(50,100)}$	$^{50}4.20$	$^{100}4.00$
Tabellaria fenestrata	$^{2}5.16_{(100)}$	$^{0}5.13_{(100)}$	$^{10}5.09_{(100)}$	$^{15}5.05_{(100)}$	$^{5}4.89$	$^{30}4.65$	$^{50}4.10$	$^{100}3.37$
Tabellaria flocculosa	$^{15}2.16$	$^{0}1.90$	$^{5}1.89$	$^{10}1.86$	$^{2}1.71$	$^{30}1.52$	$^{50}1.07$	$^{100}0.35$
Total net phytoplankton[A]	$^{0}6.46_{(100)}$	$^{2}6.29_{(100)}$	$^{15}6.20_{(100)}$	$^{5}6.18_{(100)}$	$^{10}6.13_{(100)}$	$^{30}5.57$	$^{50}5.09$	$^{100}4.64$

[A]Total also includes taxa not listed in table.

Table 5. Results of multiple comparisons testing for depths for the more important net phytoplankton taxa and total net phytoplankton, autumn 2002. The superscript associated with each LSMean denotes the depth and the subscript refers to a depth or depths from which it differs significantly ($P < 0.05$).

Taxon/Grouping	LSMeans (descending order)							
Chrysophyta								
Dinobryon bavaricum	$^{2}0.61$	$^{10}0.44$	$^{15}0.27$	$^{0}0.23$	^{100}-0.01	^{50}-0.01	^{30}-0.01	^{5}-0.01
Dinobryon sertularia								
Dinobryon cylindricum	$^{15}0.20$	^{100}-0.003	^{50}-0.003	^{30}-0.003	^{10}-0.003	^{5}-0.003	^{2}-0.003	^{0}-0.003
Bacillariophyta								
Asterionella formosa	$^{30}4.31$	$^{5}4.28$	$^{15}4.24$	$^{100}4.23$	$^{10}4.10$	$^{2}4.10$	$^{50}3.91$	$^{0}3.84$
Tabellaria fenestrata	$^{10}5.08$	$^{50}4.77$	$^{5}4.73$	$^{2}4.71$	$^{0}4.68$	$^{15}4.58$	$^{30}4.31$	$^{100}4.14$
Tabellaria flocculosa	$^{5}0.78$	$^{2}0.50$	$^{0}0.49$	$^{15}0.40$	$^{50}0.28$	$^{30}0.22$	$^{100}0.04$	$^{10}0.04$
Total net phytoplankton[A]	$^{10}5.46$	$^{15}5.31$	$^{5}5.27$	$^{30}5.21$	$^{2}5.21$	$^{50}5.18$	$^{0}5.16$	$^{100}5.02$

[A]Total also includes taxa not listed in table.

Table 6. Results of multiple comparisons testing for depths for the more important net phytoplankton taxa and total net phytoplankton, spring 2003. The superscript associated with each LSMean denotes the depth and the subscript refers to a depth or depths from which it differs significantly ($P < 0.05$).

Taxon/Grouping	LSMeans (descending order)							
Chrysophyta								
Dinobryon bavaricum								
Dinobryon sertularia	$^{30}0.47$	$^{100}0.00$	$^{50}0.00$	$^{15}0.00$	$^{10}0.00$	$^{5}0.00$	$^{2}0.00$	$^{0}0.00$
Dinobryon cylindricum								
Bacillariophyta								
Asterionella formosa	$^{0}3.94$	$^{100}3.55$	$^{10}3.53$	$^{15}3.42$	$^{30}3.41$	$^{50}3.19$	$^{2}3.09$	$^{5}3.04$
Tabellaria fenestrata	$^{0}3.32$	$^{100}3.08$	$^{2}3.08$	$^{30}3.03$	$^{15}2.91$	$^{10}2.84$	$^{50}2.66$	$^{5}2.64$
Tabellaria flocculosa	$^{50}0.25$	$^{0}0.17$	$^{100}0.00$	$^{30}0.00$	$^{15}0.00$	$^{10}0.00$	$^{5}0.00$	$^{2}0.00$
Total net phytoplankton[A]	$^{0}4.41$	$^{100}4.24$	$^{30}4.13$	$^{10}4.02$	$^{15}4.00$	$^{50}3.89$	$^{2}3.83$	$^{5}3.64$

[A]Total also includes taxa not listed in table.

Table 7. Results of multiple comparisons testing for depths for the more important net phytoplankton taxa and total net phytoplankton, summer 2003. The superscript associated with each LSMean denotes the depth and the subscript refers to a depth or depths from which it differs significantly ($P < 0.05$).

Taxon/Grouping	LSMeans (descending order)										
Chrysophyta											
Dinobryon bavaricum	$^{0}4.59$	$^{2}4.50$	$^{250}4.16$	$^{5}4.11$	$^{150}4.09$	$^{200}4.04$	$^{10}3.39$	$^{30}3.36$	$^{15}3.34$	$^{50}3.06$	$^{100}2.89$
Dinobryon sertularia	$^{250}4.48$	$^{150}4.14$	$^{2}3.90$	$^{5}3.61$	$^{0}3.57$	$^{10}3.40$	$^{15}3.30$	$^{200}2.55$	$^{30}2.54$	$^{100}2.45$	$^{50}1.92$
Dinobryon cylindricum	$^{2}2.85$	$^{5}2.69$	$^{150}2.61$	$^{0}2.45$	$^{250}2.43$	$^{200}1.83$	$^{15}1.75$	$^{30}1.70$	$^{10}1.46$	$^{50}1.23$	$^{100}0.93$
Bacillariophyta											
Asterionella formosa	$^{250}6.96$	$^{150}6.74$	$^{200}6.50$	$^{15}6.45$	$^{50}6.33$	$^{30}6.27$	$^{10}6.13$	$^{5}6.05$	$^{2}6.04$	$^{100}5.33$	$^{0}5.31$
Tabellaria fenestrata	$^{2}5.88$	$^{250}5.53$	$^{15}5.38$	$^{5}5.36$	$^{0}5.32$	$^{10}5.31$	$^{150}5.21$	$^{30}5.00$	$^{200}4.51$	$^{50}4.39$	$^{100}3.70$
Tabellaria flocculosa	$^{250}3.48$	$^{10}1.56$	$^{0}1.50$	$^{2}1.26$	$^{30}1.24$	$^{50}1.07$	$^{150}0.95$	$^{15}0.89$	$^{5}0.79$	$^{200}0.50$	$^{100}0.49$
Total net-phytoplankton[A]	$^{2}7.39$	$^{150}7.29$	$^{250}7.35$	$^{5}7.06$	$^{15}6.99$	$^{0}6.91$	$^{200}6.86$	$^{10}6.81$	$^{30}6.79$	$^{50}6.64$	$^{100}5.76$

[A]Total also includes taxa not listed in table.

Table 8. Results of GLM analyses for the more important zooplankton taxa and groupings of taxa.

Taxon/Grouping		Model				Station				Depth (m)			
		Summer/02	Autumn/02	Spring/03	Summer/03	Summer/02	Autumn/02	Spring/03	Summer/03	Summer/02	Autumn/02	Spring/03	Summer/03
		df = 9, 95	df = 9, 54	df = 9, 62	df = 12, 84	df = 2	df = 2	df = 2	df = 2	df = 7	df = 7	df = 7	df = 10
Rotifera													
Kellicottia longispina	F	0.84	1.31	0.50	0.95	1.30	4.43	0.57	2.39	0.70	0.42	0.48	0.61
	P	0.5849	0.2544	0.8706	0.5049	0.2780	0.0166	0.5704	0.0975	0.6686	0.8871	0.8470	0.8020
Pleosoma truncatum	F	1.93	1.28		2.22	5.17	2.46		3.83	1.00	0.94		2.00
	P	0.0569	0.2691		0.0173	0.0074	0.0951		0.0255	0.4356	0.4814		0.0433
Total[A]	F	3.33	1.33	0.36	0.76	8.35	4.50	0.09	1.25	1.89	0.43	0.43	0.64
	P	0.0014	0.2427	0.9511	0.6933	0.0005	0.0155	0.9135	0.2909	0.072	0.8819	0.8782	0.7793
Cladocera													
Bosminidae	F	3.79	0.84	0.90	2.54	13.85	2.04	0.76	3.81	0.92	0.50	0.94	2.28
	P	0.0004	0.5837	0.5291	0.0065	< 0.0001	0.5000	0.4731	0.0261	0.4967	0.8327	0.4801	0.0203
Total[A]	F	3.30	1.14	1.01	2.44	11.76	2.43	0.77	3.96	0.88	0.77	1.07	2.13
	P	0.0015	0.3525	0.4452	0.0089	< 0.0001	0.0979	0.4673	0.0227	0.5269	0.6141	0.3914	0.0305
Copepoda													
Nauplii	F	6.74	1.22	2.66	2.93	3.49	1.30	5.10	0.68	7.67	1.19	1.96	3.38
	P	< 0.0001	0.3045	0.0112	0.0020	0.0343	0.2813	0.0089	0.5095	< 0.0001	0.3225	0.0744	0.0009
Diaptomid copepodites	F	2.42	0.66	0.48	0.88	8.29	1.96	0.38	4.41	0.74	0.29	0.50	0.13
	P	0.0160	0.7370	0.8859	0.5712	0.0005	0.1501	0.6839	0.0151	0.6353	0.9539	0.8298	0.9930
Leptodiaptomus minutus	F	3.59	0.79	4.95	6.91	4.50	2.00	18.84	4.93	3.33	0.45	0.98	7.25
	P	0.0007	0.6245	<0.0001	<0.0001	0.0136	0.1457	<0.0001	0.0094	0.0033	0.8669	0.4565	<0.0001
Cyclopoid copepodites	F	1.10	1.37	3.12	2.86	0.11	3.80	7.59	0.00	1.38	0.68	1.85	3.43
	P	0.3698	0.2232	0.0037	0.0024	0.8984	0.0287	0.0011	0.9978	0.2207	0.6872	0.0938	0.0008
Cyclops scutifer	F	4.85	1.34	0.77	6.76	0.45	1.08	0.50	0.32	6.11	1.42	0.85	8.01
	P	<0.0001	0.2381	0.6448	<0.0001	0.6413	0.3456	0.6087	0.7290	<0.0001	0.2184	0.5538	<0.0001
Total[A] (nauplii excluded)	F	1.13	0.98	5.00	1.32	3.63	3.16	18.81	5.22	0.42	0.36	1.06	0.51
	P	0.3465	0.4658	<0.0001	0.2224	0.0303	0.0506	<0.0001	0.0073	0.8864	0.9212	0.4006	0.8787
Total Microcrustacea[A]	F	2.15	0.90	4.99	1.26	7.55	2.86	13.02	4.77	0.60	0.34	2.70	0.54
(nauplii excluded)	P	0.0328	0.5325	<0.0001	0.2556	0.0009	0.0661	<0.0001	0.0109	0.7547	0.9322	0.0165	0.8604
Total zooplankton[A]	F	3.33	1.33	0.36	0.76	8.35	4.50	0.09	1.25	1.89	0.43	0.43	0.64
(nauplii included)	P	0.0014	0.2427	0.9511	0.6933	0.0005	0.0155	0.9135	0.2909	0.0792	0.8819	0.8782	0.7793

[A]Total also includes taxa not listed in table.

Table 9. Results of multiple comparisons testing for stations for the more important zooplankton taxa and groupings of taxa. The superscript associated with each LSMean denotes the station and the subscript refers to a station or stations from which it differs significantly ($P < 0.05$).

Taxon/Grouping	LSMeans (descending order)											
	Summer/02			Autumn/02			Spring/03			Summer/03		
Rotifera												
Kellicottia longispina	$^{3}3.87$	$^{2}3.59$	$^{1}2.60$	$^{2}3.61_{(1)}$	$^{3}3.39$	$^{1}1.05$	$^{2}0.76$	$^{1}0.75$	$^{2}0.26$	$^{2}3.31$	$^{3}3.27$	$^{1}1.82$
Pleosoma truncatum	$^{3}3.00_{(1)}$	$^{2}1.56$	$^{1}0.71$	$^{2}1.04$	$^{1}0.37$	$^{1}0.00$				$^{3}3.86_{(1)}$	$^{2}2.28$	$^{1}1.77$
Total[A]	$^{3}6.46_{(1)}$	$^{2}4.84$	$^{1}3.49$	$^{2}3.67_{(1)}$	$^{3}3.39$	$^{1}1.05$	$^{1}0.99$	$^{2}0.76$	$^{2}0.76$	$^{2}5.18$	$^{3}5.16$	$^{1}3.97$
Cladocera												
Bosminidae	$^{3}3.85_{(1)}$	$^{2}2.73_{(1)}$	$^{1}1.10$	$^{3}3.89$	$^{2}2.94$	$^{1}2.69$	$^{1}1.91$	$^{2}1.45$	$^{3}1.31$	$^{3}4.11_{(1)}$	$^{2}4.11_{(1)}$	$^{1}3.18$
Total[A]	$^{3}4.18_{(1)}$	$^{2}3.07_{(1)}$	$^{1}1.66$	$^{3}4.09$	$^{2}3.01$	$^{1}2.96$	$^{1}1.91$	$^{2}1.85$	$^{3}1.33$	$^{3}4.27_{(1)}$	$^{3}4.25_{(1)}$	$^{1}3.30$
Copepoda												
Nauplii	$^{3}6.65_{(1)}$	$^{2}6.36$	$^{1}5.60$	$^{2}6.35$	$^{1}5.79$	$^{1}5.38$	$^{3}4.72_{(1)}$	$^{2}3.93$	$^{1}2.85$	$^{2}8.63$	$^{3}8.49$	$^{1}8.33$
Diaptomid copepodids	$^{2}5.44_{(1)}$	$^{3}5.34_{(1)}$	$^{1}3.55$	$^{2}5.42$	$^{3}5.38$	$^{1}5.09$	$^{1}1.01$	$^{1}0.70$	$^{2}0.67$	$^{2}6.17_{(1)}$	$^{3}5.31$	$^{1}3.72$
Leptodiaptomus minutus	$^{2}2.53_{(1)}$	$^{3}2.35_{(1)}$	$^{1}1.33$	$^{2}3.53$	$^{3}2.64$	$^{1}2.55$	$^{2}4.11_{(1)}$	$^{3}3.27_{(1)}$	$^{1}1.46$	$^{2}5.21_{(1)}$	$^{3}4.71$	$^{1}4.09$
Cyclopoid copepodids	$^{2}3.02$	$^{1}2.97$	$^{3}2.81$	$^{2}4.00_{(3)}$	$^{1}3.31$	$^{3}2.63$	$^{2}1.94_{(1)}$	$^{3}1.37_{(1)}$	$^{1}0.30$	$^{2}4.33$	$^{1}4.32$	$^{3}4.30$
Cyclops scutifer	$^{3}0.86$	$^{1}0.65$	$^{2}0.62$	$^{2}0.94$	$^{1}0.45$	$^{3}0.44$	$^{1}0.16$	$^{2}0.13$	$^{1}0.00$	$^{3}3.17$	$^{2}3.06$	$^{1}2.80$
Total[A] (nauplii excluded)	$^{2}5.99_{(1)}$	$^{3}5.97_{(1)}$	$^{1}5.11$	$^{2}5.91_{(1)}$	$^{3}5.72$	$^{1}5.49$	$^{2}4.57_{(1)}$	$^{3}3.75_{(1)}$	$^{1}2.00$	$^{2}7.52_{(1)}$	$^{3}7.01$	$^{1}5.96$
Total Microcrustacea[A] (nauplii excluded)	$^{3}6.55_{(1)}$	$^{2}6.15_{(1)}$	$^{1}5.18$	$^{2}6.03$	$^{3}5.95$	$^{1}5.67$	$^{2}4.73_{(1)}$	$^{3}4.15_{(1)}$	$^{1}3.07$	$^{2}7.59_{(1)}$	$^{3}7.14$	$^{1}6.34$
Total zooplankton[A] (nauplii included)	$^{3}8.29_{(1)}$	$^{2}8.00_{(1)}$	$^{1}7.08$	$^{2}7.53_{(1)}$	$^{3}7.10$	$^{1}6.72$	$^{2}7.38$	$^{1}7.27$	$^{2}7.06$	$^{2}9.44$	$^{1}9.13$	$^{1}9.00$

[A]Total also includes taxa not listed in table.

Table 10. Results of multiple comparisons testing for depths for the more important zooplankton taxa and groupings of taxa, summer 2002. The superscript associated with each LSMean denotes the depth and the subscript refers to a depth or depths from which it differs significantly ($P < 0.05$).

Taxon/Grouping	LSMeans (descending order)							
Rotifera								
Kellicottia longispina	$^{5}4.25$	$^{15}4.17$	$^{2}3.89$	$^{10}3.75$	$^{0}3.69$	$^{50}2.86$	$^{30}2.20$	$^{100}2.07$
Pleosoma truncatum	$^{0}2.93$	$^{5}2.47$	$^{2}2.29$	$^{30}2.08$	$^{15}1.78$	$^{10}1.35$	$^{100}1.16$	$^{50}0.00$
Total[A]	$^{0}6.31$	$^{2}5.58$	$^{10}5.56$	$^{2}5.47$	$^{100}5.43$	$^{15}4.86$	$^{30}3.23$	$^{50}3.01$
Cladocera								
Bosminidae	$^{15}3.38$	$^{30}3.20$	$^{50}3.10$	$^{5}2.65$	$^{10}2.36$	$^{0}2.10$	$^{2}2.06$	$^{100}1.63$
Total[A]	$^{15}3.59$	$^{30}3.57$	$^{50}3.29$	$^{100}3.09$	$^{10}2.92$	$^{5}2.87$	$^{2}2.31$	$^{0}2.15$
Copepoda								
Nauplii	$^{2}7.42_{(50,100)}$	$^{10}7.29_{(50,100)}$	$^{0}7.28_{(50,100)}$	$^{5}7.27_{(50,100)}$	$^{15}6.88_{(50,100)}$	$^{30}6.04_{(50)}$	$^{50}3.75$	$^{100}3.72$
Diaptomid copepodites	$^{15}5.24$	$^{2}5.22$	$^{10}5.22$	$^{5}5.16$	$^{50}4.84$	$^{0}4.37$	$^{100}4.10$	$^{30}4.03$
Leptodiaptomus minutus	$^{30}3.39_{(10)}$	$^{100}2.72$	$^{50}2.67$	$^{15}2.21$	$^{0}1.89$	$^{2}1.62$	$^{5}1.57$	$^{10}0.50$
Cyclopoid copepodites	$^{50}3.73$	$^{30}3.58$	$^{15}3.36$	$^{10}2.93$	$^{100}2.83$	$^{5}2.71$	$^{2}2.44$	$^{0}1.88$
Cyclops scutifer	$^{50}1.98_{(0,2,5,10,15,100)}$	$^{30}1.79_{(0,2,5,10,15,100)}$	$^{100}1.25$	$^{5}0.43$	$^{2}0.21$	$^{15}0.00$	$^{10}0.00$	$^{0}0.00$
Total[A] (nauplii excluded)	$^{15}6.12$	$^{50}5.95$	$^{30}5.81$	$^{2}5.68$	$^{5}5.62$	$^{10}5.61$	$^{100}5.49$	$^{0}5.23$
Total Microcrustacea[A] (nauplii excluded)	$^{15}6.46$	$^{50}6.10$	$^{10}6.06$	$^{5}6.03$	$^{30}6.02$	$^{2}5.93$	$^{100}5.70$	$^{0}5.38$
Total zooplankton[A] (nauplii included)	$^{5}8.44_{(50,100)}$	$^{2}8.28_{(50,100)}$	$^{10}8.21_{(50)}$	$^{0}8.18_{(50)}$	$^{15}8.11_{(50)}$	$^{30}7.43$	$^{100}6.86$	$^{50}6.82$

[A]Total also includes taxa not listed in table.

Table 11. Results of multiple comparisons testing for depths for the more important zooplankton taxa and groupings of taxa, autumn 2002. The superscript associated with each LSMean denotes the depth and the subscript refers to a depth or depths from which it differs significantly ($P < 0.05$).

Taxon/Grouping	LSMeans (descending order)							
Rotifera								
Kellicottia longispina	$^{15}4.30$	$^{5}2.71$	$^{0}2.70$	$^{2}2.62$	$^{15}2.62$	$^{30}2.48$	$^{50}2.35$	$^{100}1.68$
Pleosoma truncatum	$^{5}1.45$	$^{10}0.84$	$^{2}0.75$	$^{15}0.72$	$^{0}-0.01$	$^{30}-0.01$	$^{50}-0.01$	$^{100}-0.01$
Total[A]	$^{15}4.34$	$^{5}2.81$	$^{0}2.70$	$^{2}2.65$	$^{15}2.64$	$^{30}2.48$	$^{50}2.35$	$^{100}1.68$
Cladocera								
Bosminidae	$^{30}3.91$	$^{2}3.65$	$^{100}3.55$	$^{15}3.07$	$^{5}2.93$	$^{50}2.93$	$^{0}2.78$	$^{10}2.56$
Total[A]	$^{30}4.32$	$^{100}3.75$	$^{2}3.65$	$^{5}3.34$	$^{0}3.19$	$^{15}3.07$	$^{50}2.97$	$^{10}2.56$
Copepoda								
Nauplii	$^{15}6.81$	$^{0}6.51$	$^{10}6.25$	$^{50}6.22$	$^{5}5.89$	$^{2}5.77$	$^{30}4.67$	$^{100}4.62$
Diaptomid copepodites	$^{15}5.46$	$^{10}5.40$	$^{50}5.38$	$^{0}5.31$	$^{30}5.30$	$^{100}5.21$	$^{5}5.16$	$^{2}5.14$
Leptodiaptomus minutus	$^{30}3.50$	$^{50}3.38$	$^{100}3.24$	$^{15}2.89$	$^{0}2.87$	$^{2}2.63$	$^{10}2.47$	$^{5}2.30$
Cyclopoid copepodites	$^{15}3.99$	$^{100}3.97$	$^{5}3.35$	$^{50}3.20$	$^{5}3.19$	$^{2}3.03$	$^{30}3.02$	$^{10}2.74$
Cyclops scutifer	$^{50}1.80$	$^{30}0.78$	$^{15}0.79$	$^{100}0.38$	$^{10}0.38$	$^{5}0.38$	$^{0}0.38$	$^{2}-0.02$
Total[A] (nauplii excluded)	$^{15}5.90$	$^{10}5.81$	$^{100}5.78$	$^{0}5.72$	$^{10}5.70$	$^{30}5.57$	$^{5}5.57$	$^{2}5.53$
Total Microcrustacea[A] (nauplii excluded)	$^{15}6.00$	$^{10}5.98$	$^{100}5.97$	$^{50}5.96$	$^{0}5.88$	$^{10}5.81$	$^{2}5.76$	$^{5}5.71$
Total zooplankton[A] (nauplii included)	$^{15}7.44$	$^{10}7.43$	$^{0}7.39$	$^{50}7.09$	$^{5}6.99$	$^{2}6.98$	$^{30}6.83$	$^{100}6.81$

[A]Total also includes taxa not listed in table.

Table 12. Results of multiple comparisons testing for depths for the more important zooplankton taxa and groupings of taxa, spring 2003. The superscript associated with each LSMean denotes the depth and the subscript refers to a depth or depths from which it differs significantly ($P < 0.05$).

Taxon/Grouping	LSMeans (descending order)							
Rotifera								
Kellicottia longispina	$^{30}1.34$	$^{100}0.68$	$^{50}0.68$	$^{5}0.68$	$^{10}0.65$	$^{0}0.65$	$^{15}0.00$	$^{2}0.00$
Pleosoma truncatum								
Total[A]	$^{100}1.37$	$^{30}1.34$	$^{5}1.34$	$^{50}0.68$	$^{10}0.65$	$^{2}0.65$	$^{0}0.65$	$^{15}0.00$
Cladocera								
Bosminidae	$^{15}2.44$	$^{100}2.02$	$^{50}1.79$	$^{30}1.62$	$^{2}1.50$	$^{0}1.43$	$^{5}1.15$	$^{10}0.51$
Total[A]	$^{15}2.44$	$^{30}2.33$	$^{100}2.02$	$^{50}1.86$	$^{5}1.50$	$^{2}1.50$	$^{0}1.43$	$^{10}0.50$
Copepoda								
Nauplii	$^{5}4.73$	$^{10}4.60$	$^{2}4.51$	$^{0}4.26$	$^{15}4.00$	$^{30}3.51$	$^{50}3.17$	$^{100}1.90$
Diaptomid copepodites	$^{2}1.43$	$^{100}1.15$	$^{15}0.83$	$^{50}0.71$	$^{10}0.71$	$^{0}0.71$	$^{5}0.43$	$^{30}0.36$
Leptodiaptomus minutus	$^{100}3.73$	$^{30}3.42$	$^{50}3.12$	$^{15}3.08$	$^{0}2.87$	$^{2}2.65$	$^{5}2.59$	$^{10}2.13$
Cyclopoid copepodites	$^{100}2.41$	$^{30}1.62$	$^{50}1.50$	$^{15}1.50$	$^{0}0.79$	$^{10}0.72$	$^{2}0.72$	$^{5}0.36$
Cyclops scutifer	$^{100}0.00$	$^{50}0.00$	$^{30}0.00$	$^{15}0.00$	$^{10}0.36$	$^{5}0.00$	$^{2}0.43$	$^{0}0.00$
Total[A] (nauplii excluded)	$^{100}4.14$	$^{15}3.88$	$^{50}3.73$	$^{30}3.61$	$^{0}3.45$	$^{2}3.23$	$^{10}2.75$	$^{5}2.73$
Total Microcrustacea[A] (nauplii excluded)	$^{100}4.80_{(10)}$	$^{15}4.53_{(10)}$	$^{50}4.26$	$^{30}4.23$	$^{0}3.92$	$^{2}3.76$	$^{5}3.57$	$^{10}2.80$
Total zooplankton[A] (nauplii included)	$^{2}7.82$	$^{5}7.64$	$^{0}7.62$	$^{10}7.15$	$^{100}7.05$	$^{50}6.92$	$^{30}6.92$	$^{15}6.73$

[A]Total also includes taxa not listed in table.

Table 13. Results of multiple comparisons testing for depths for the more important zooplankton taxa and groupings of taxa, summer 2003. The superscript associated with each LSMean denotes the depth and the subscript refers to a depth or depths from which it differs significantly ($P < 0.05$)

Taxon/Grouping	LSMeans (descending order)										
Rotifera											
Kellicottia longispina	$^{250}6.21$	$^{150}4.17$	$^{10}3.39$	$^{2}3.03$	$^{30}2.41$	$^{5}2.40$	$^{15}2.19$	$^{100}2.08$	$^{50}1.90$	$^{0}1.74$	$^{200}1.35$
Pleosoma truncatum	$^{250}7.76$	$^{2}4.17$	$^{0}3.41$	$^{10}2.92$	$^{200}2.89$	$^{150}2.09$	$^{5}2.01$	$^{15}1.83$	$^{50}1.25$	$^{30}0.69$	$^{100}0.00$
Total[A]	$^{250}7.40$	$^{2}6.23$	$^{150}5.54$	$^{200}5.33$	$^{10}4.71$	$^{30}4.35$	$^{5}4.00$	$^{100}3.93$	$^{50}3.84$	$^{15}3.57$	$^{0}3.56$
Cladocera											
Bosminidae	$^{150}4.46$	$^{10}4.43$	$^{15}4.41$	$^{50}4.34$	$^{100}4.09$	$^{200}4.02$	$^{30}4.00$	$^{250}3.97$	$^{2}3.02$	$^{5}2.59$	$^{0}2.46$
Total[A]	$^{150}4.69$	$^{50}4.57$	$^{10}4.50$	$^{15}4.48$	$^{100}4.26$	$^{200}4.20$	$^{30}4.13$	$^{250}3.95$	$^{2}3.05$	$^{5}3.01$	$^{0}2.52$
Copepoda											
Nauplii	$^{2}9.56_{(100,200)}$	$^{5}9.55_{(100,200)}$	$^{0}9.13$	$^{10}8.43$	$^{15}8.59$	$^{30}8.38$	$^{150}8.25$	$^{250}8.17$	$^{50}8.10$	$^{100}7.91$	$^{200}7.24$
Diaptomid copepodites	$^{250}6.43$	$^{150}6.12$	$^{2}5.12$	$^{0}5.08$	$^{5}5.03$	$^{30}4.89$	$^{50}4.73$	$^{15}4.71$	$^{100}4.67$	$^{10}4.51$	$^{200}4.48$
Leptodiaptomus minutus	$^{30}6.20_{(0,2.5)}$	$^{50}5.75_{(0,2.5)}$	$^{15}5.57_{(0,2.5)}$	$^{150}5.46_{(2.5)}$	$^{200}5.30$	$^{250}5.26$	$^{100}5.04_{(2.5)}$	$^{10}4.16$	$^{0}3.12$	$^{2}2.81$	$^{5}2.72$
Cyclopoid copepodites	$^{200}5.42$	$^{30}5.16_{(0)}$	$^{10}5.00_{(0)}$	$^{150}4.97$	$^{15}4.92_{(0)}$	$^{50}4.77_{(0)}$	$^{100}4.70$	$^{250}4.26$	$^{5}3.48$	$^{2}2.63$	$^{0}2.15$
Cyclops scutifer	$^{250}5.19$	$^{30}4.86_{(0,2.5,10,15)}$	$^{50}4.76_{(0,2.5,10,15,30)}$	$^{150}4.75_{(0,2.5,10)}$	$^{200}4.09_{(5)}$	$^{100}3.48_{(5)}$	$^{15}1.75$	$^{10}1.38$	$^{0}1.29$	$^{2}0.95$	$^{5}0.60$
Total[A] (nauplii excluded)	$^{150}7.59$	$^{30}7.43$	$^{250}7.16$	$^{50}7.06$	$^{15}7.03$	$^{200}7.02$	$^{100}6.61$	$^{5}6.44$	$^{10}6.42$	$^{0}6.21$	$^{2}6.15$
Total Microcrustacea[A] (nauplii excluded)	$^{150}7.67$	$^{30}7.51$	$^{250}7.30$	$^{15}7.26$	$^{50}7.17$	$^{200}7.07$	$^{10}6.90$	$^{5}6.81$	$^{100}6.74$	$^{2}6.58$	$^{0}6.25$
Total zooplankton[A] (nauplii included)	$^{2}9.83$	$^{5}9.75$	$^{0}9.40$	$^{150}9.34$	$^{15}9.16$	$^{200}9.06$	$^{250}9.04$	$^{10}9.04$	$^{30}8.96$	$^{100}8.78$	$^{50}8.73$

[A]Total also includes taxa not listed in table.

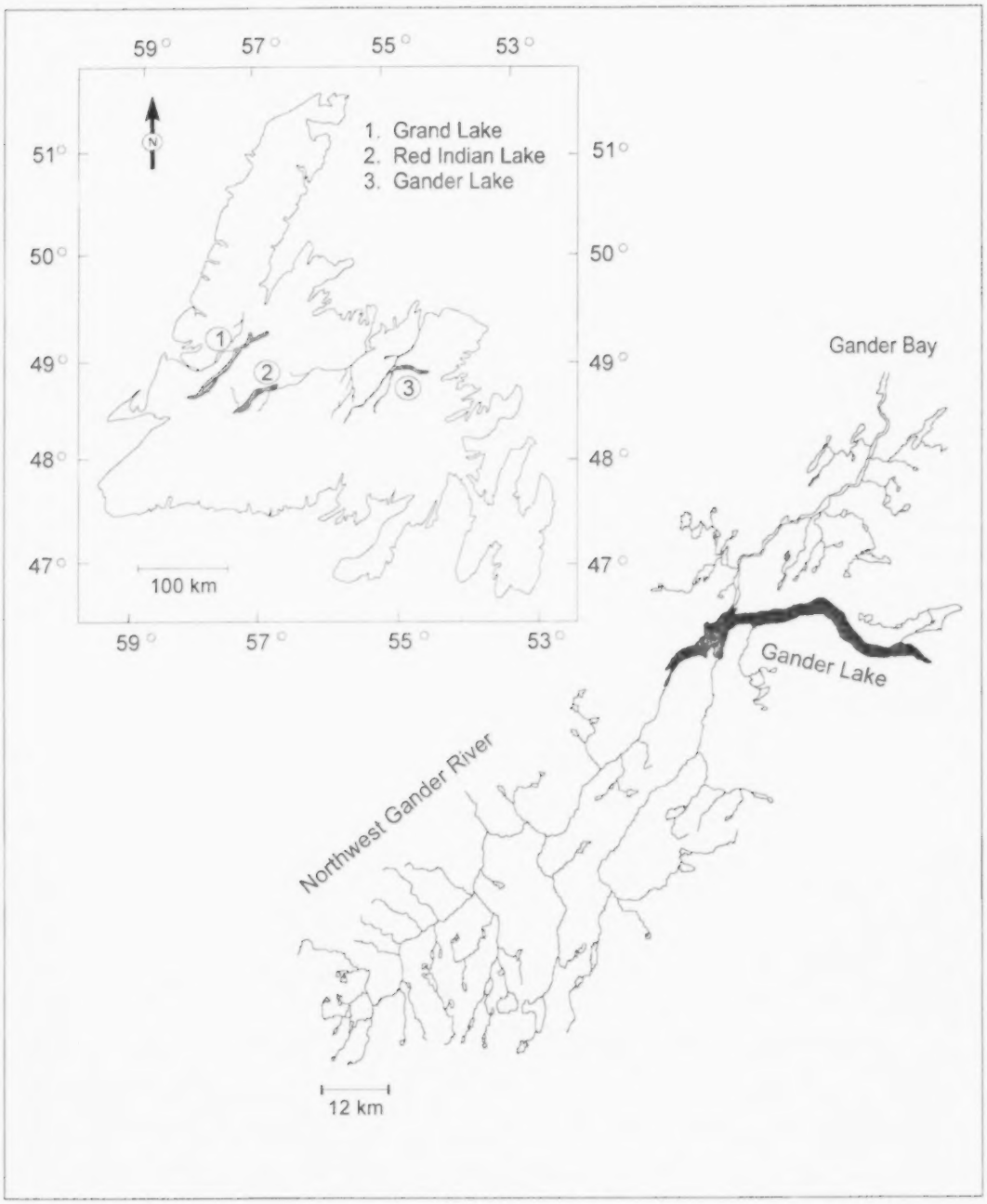

Figure 1. Map showing the location of Gander Lake and its major tributaries as well as the locations of Grand Lake and Red Indian Lake.

Figure 2. Bathymetric map (metres) and the locations of plankton sampling stations.

Figure 3. The locations of benthic macroinvertebrate sampling stations. The expanded area shows the distribution of stations off from Joe's Feeder tributary.

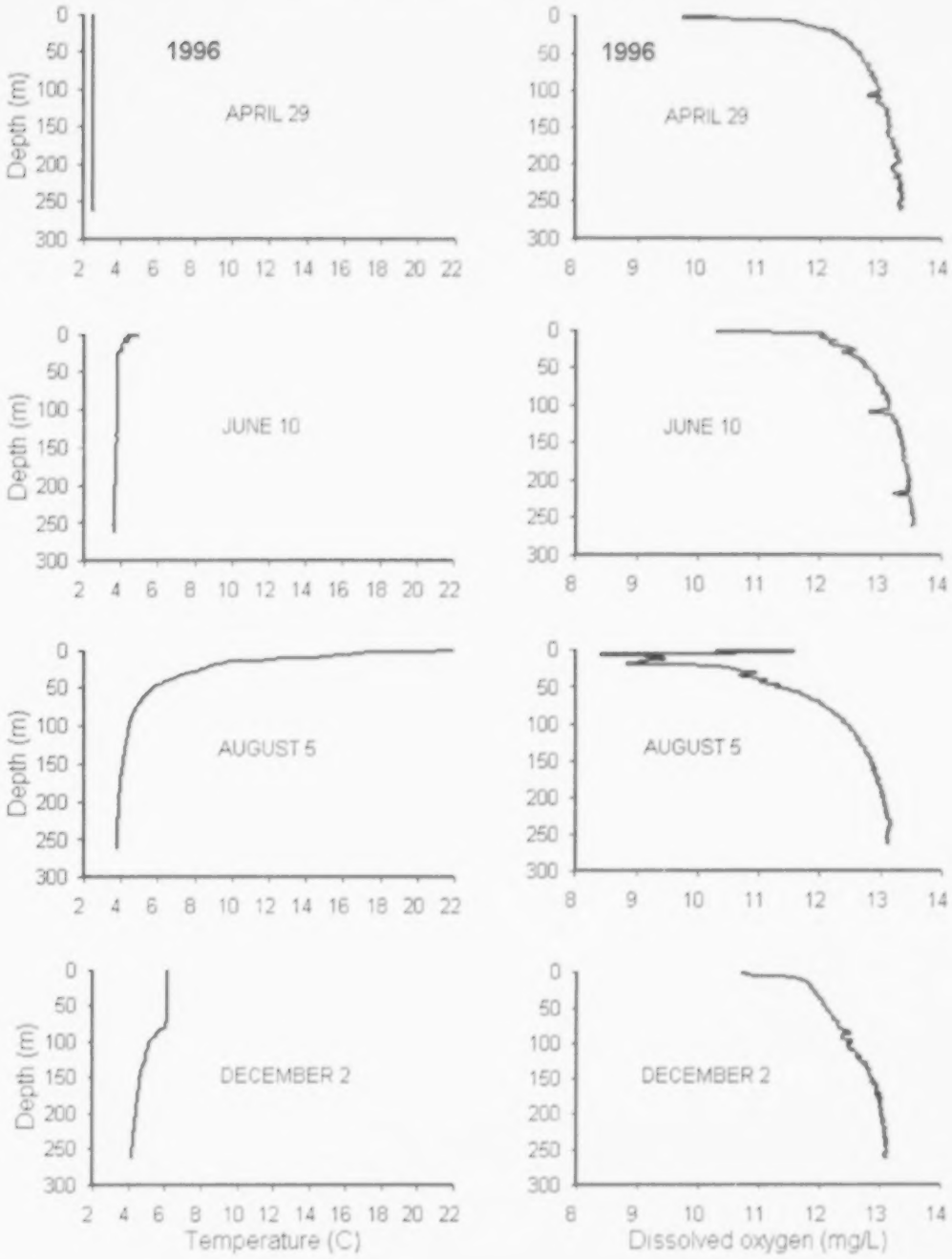

Figure 4. Water temperature and dissolved oxygen profiles, April–December, 1996.

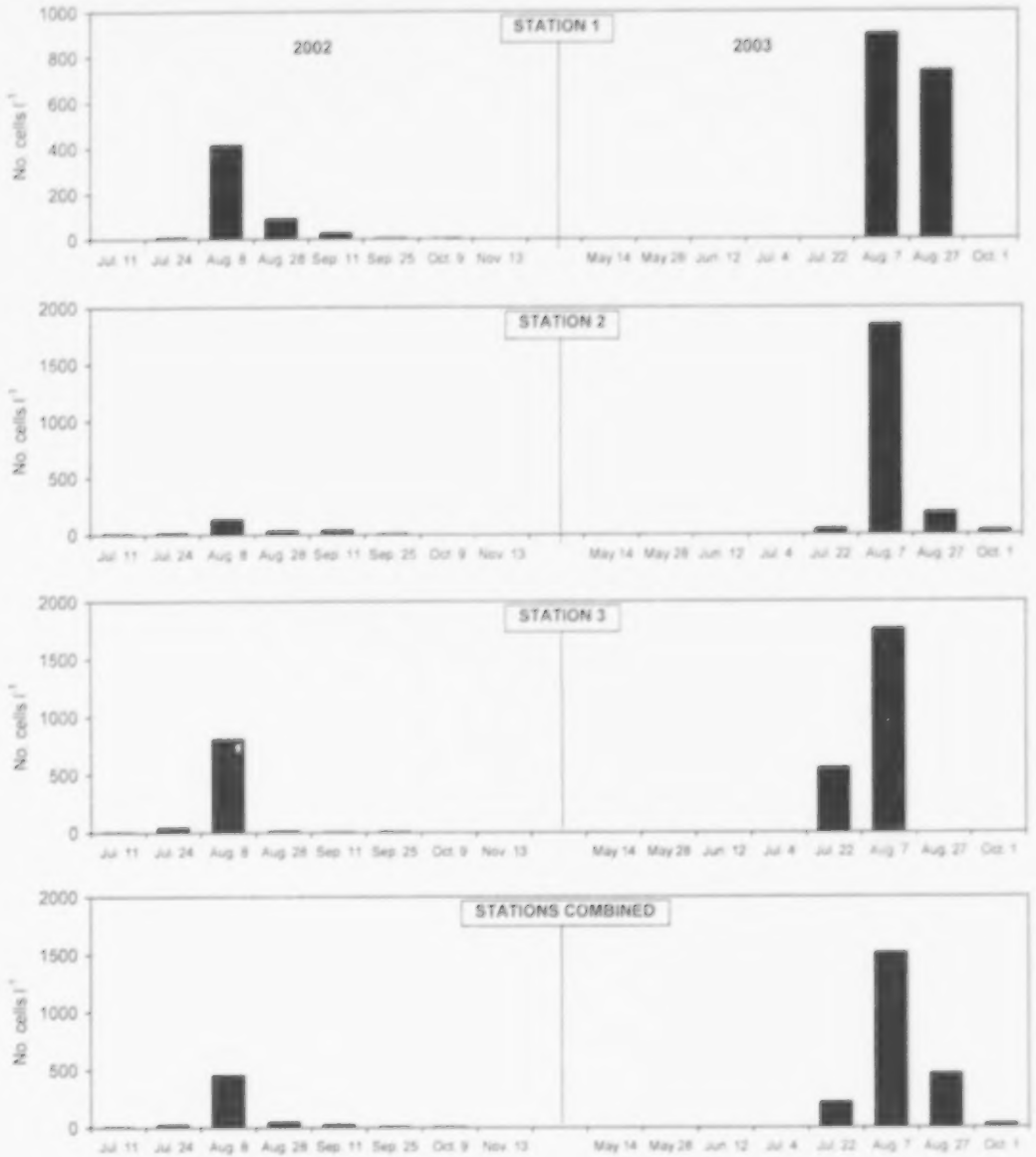

Figure 5. Seasonal distribution of *Dinobryon bavaricum* (means of depths). See text for details on stations and depths sampled on a particular date.

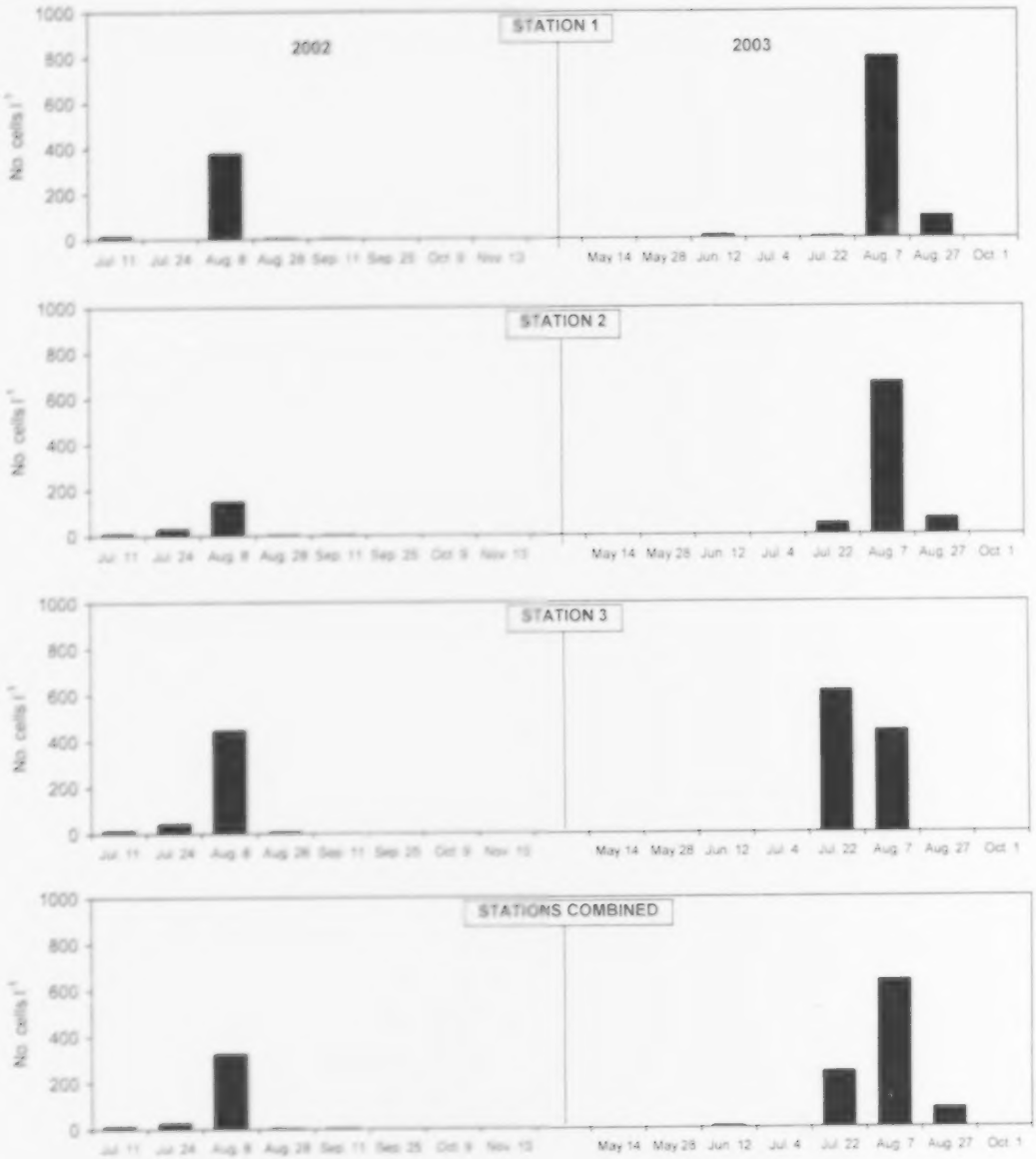

Figure 6. Seasonal distribution of *Dinobryon sertularia* (means of depths). See text for details on stations and depths sampled on a particular date.

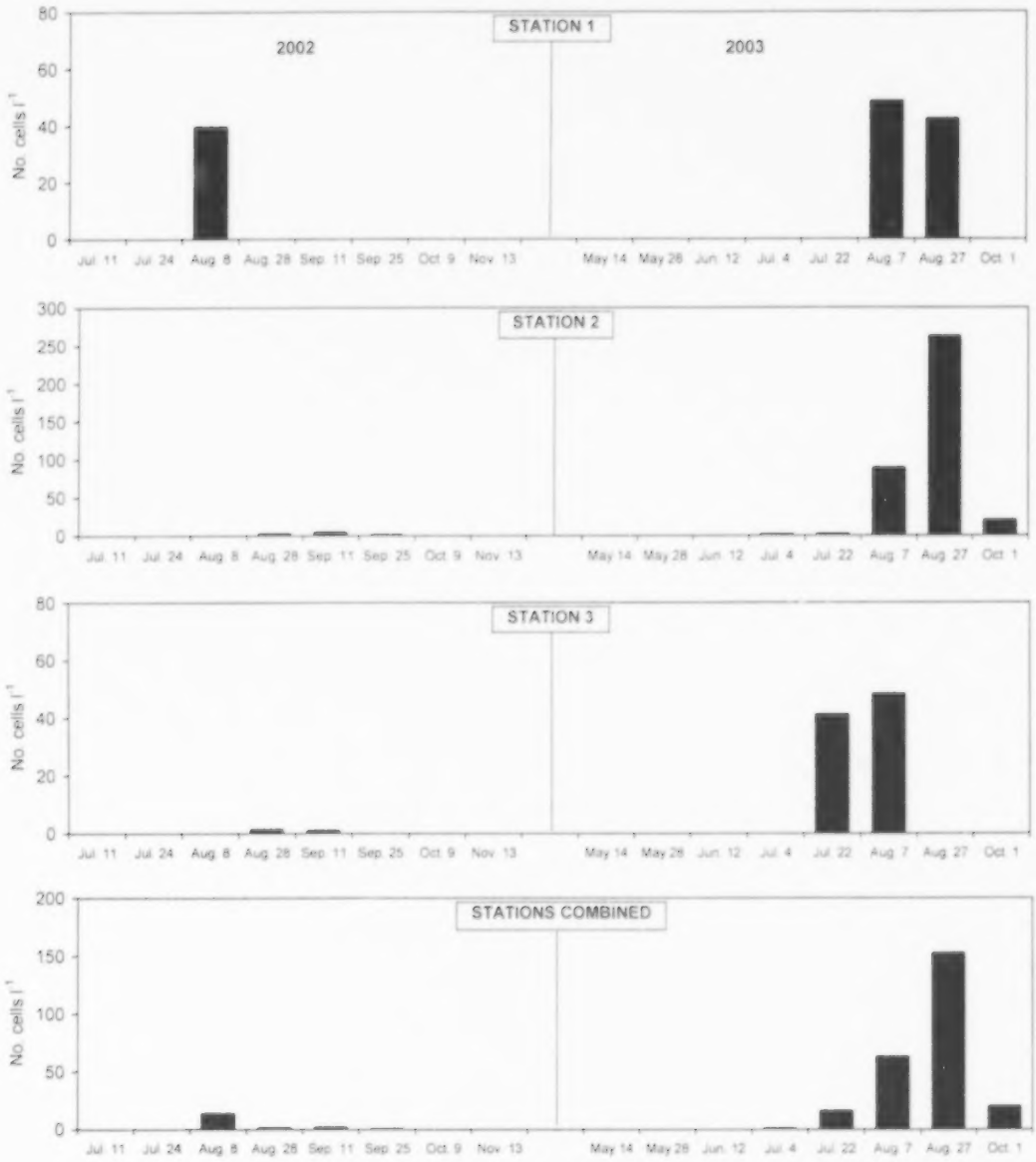

Figure 7. Seasonal distribution of *Dinobryon cylindricum* (means of depths). See text for details on stations and depths sampled on a particular date.

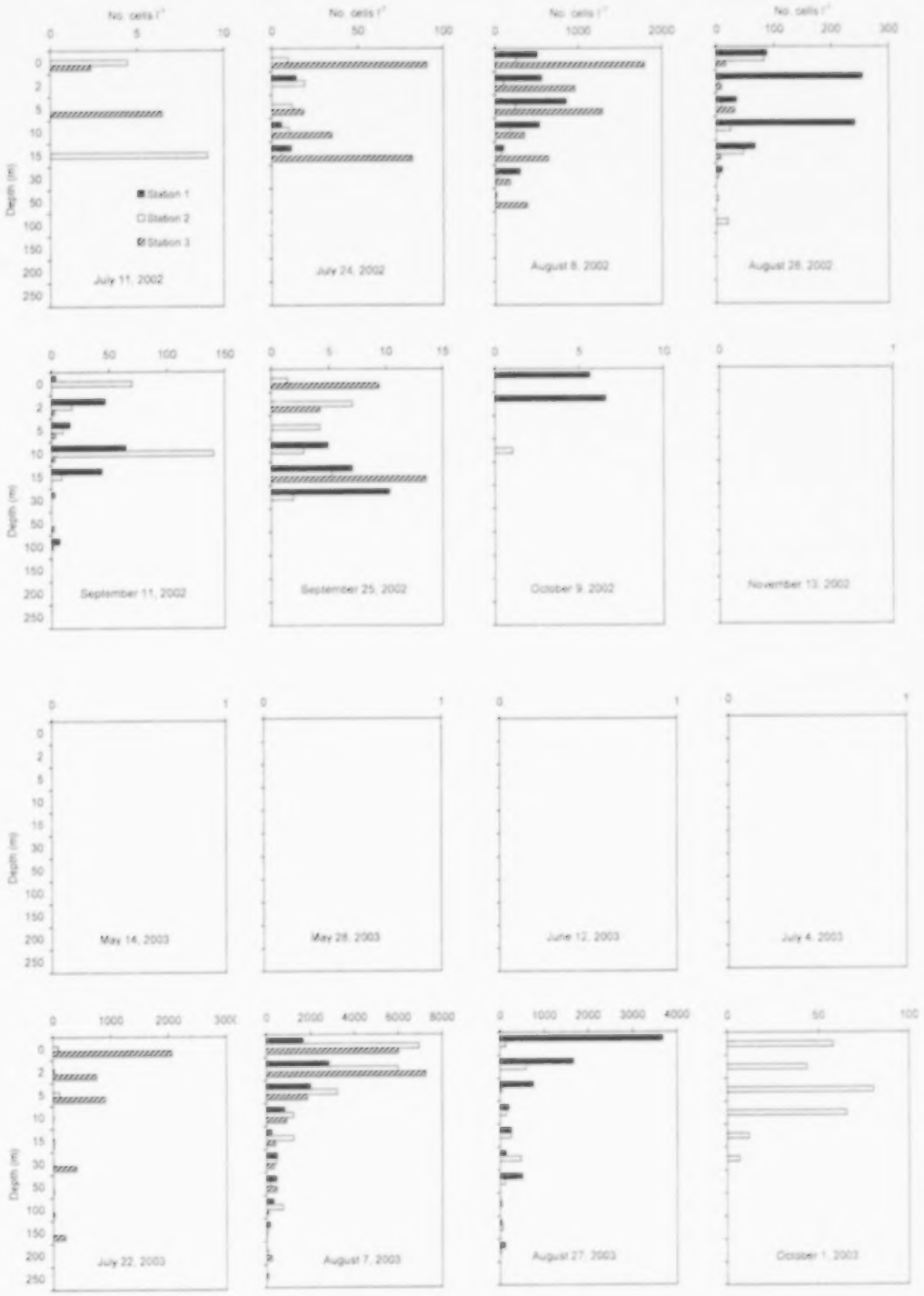

Figure 8. Vertical distribution of *Dinobryon bavaricum* by station. See text for details on stations and depths sampled on a particular date.

Figure 9. Vertical distribution of *Dinobryon sertularia* by station. See text for details on stations and depths sampled on a particular date.

Figure 10. Vertical distribution of *Dinobryon cylindricum* by station. See text for details on stations and depths sampled on a particular date.

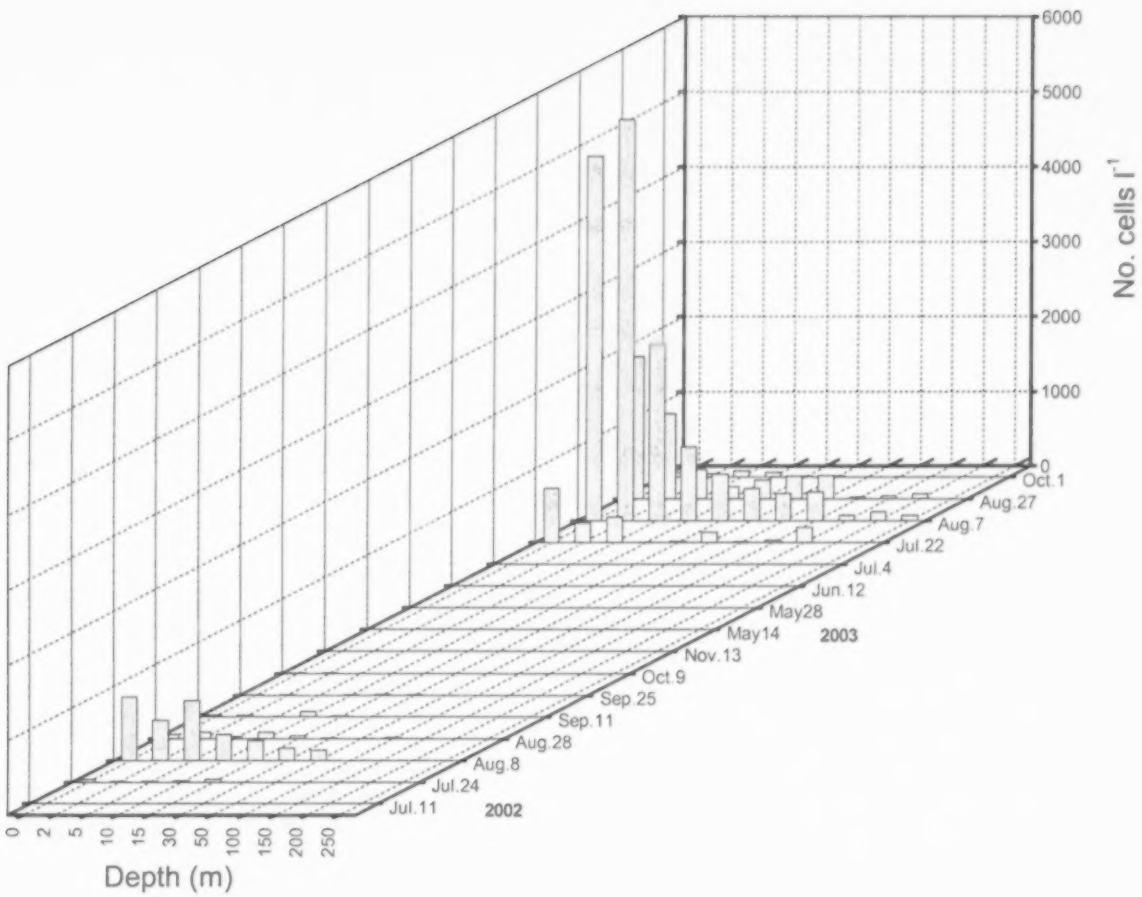

Figure 11. Vertical distribution of *Dinobryon bavaricum* (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

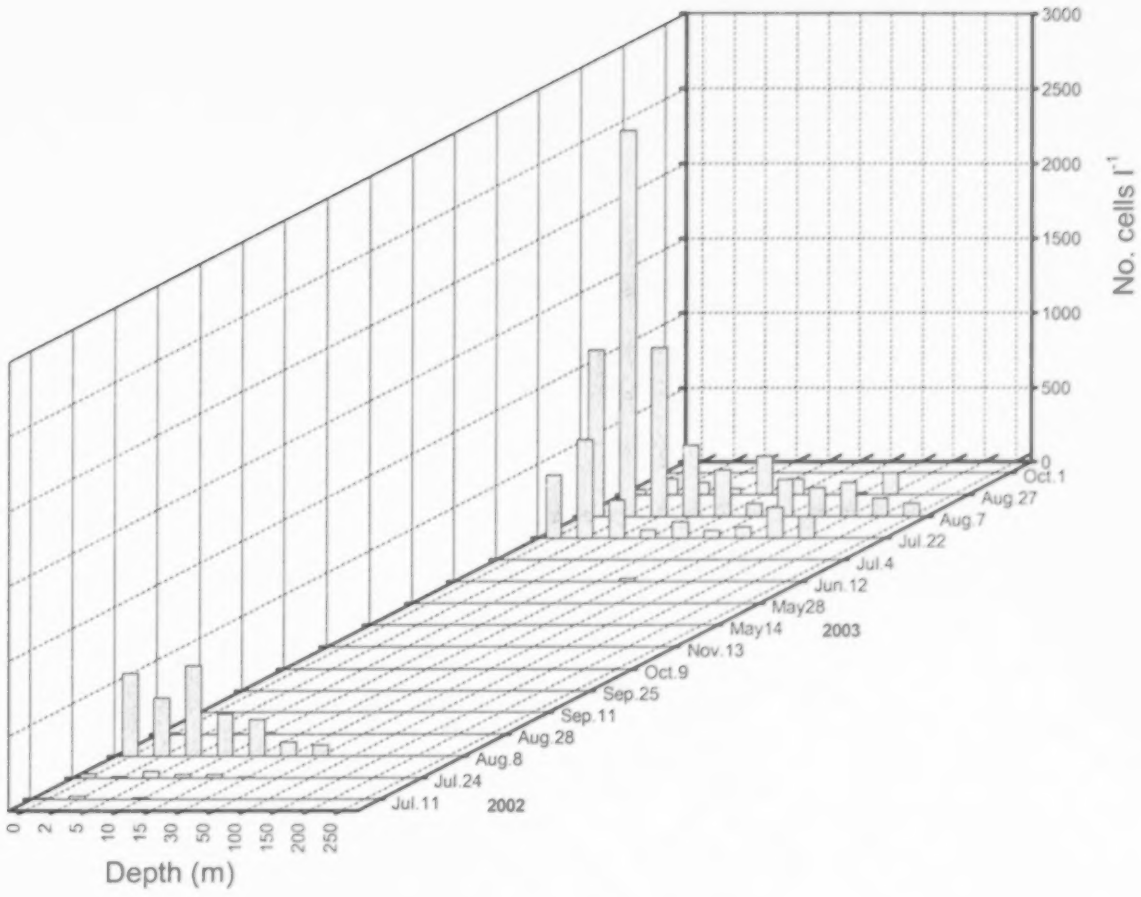

Figure 12. Vertical distribution of *Dinobryon sertularia* (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

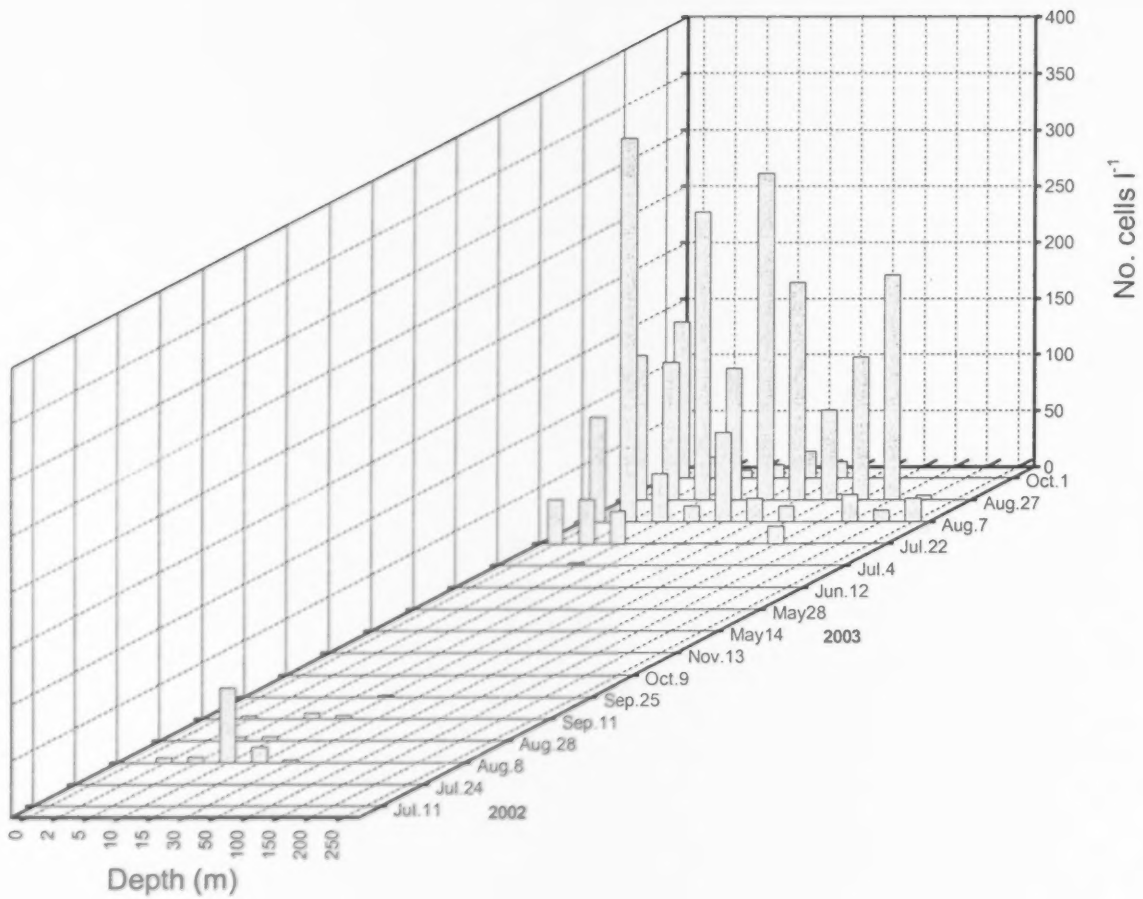

Figure 13. Vertical distribution of *Dinobryon cylindricum* (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

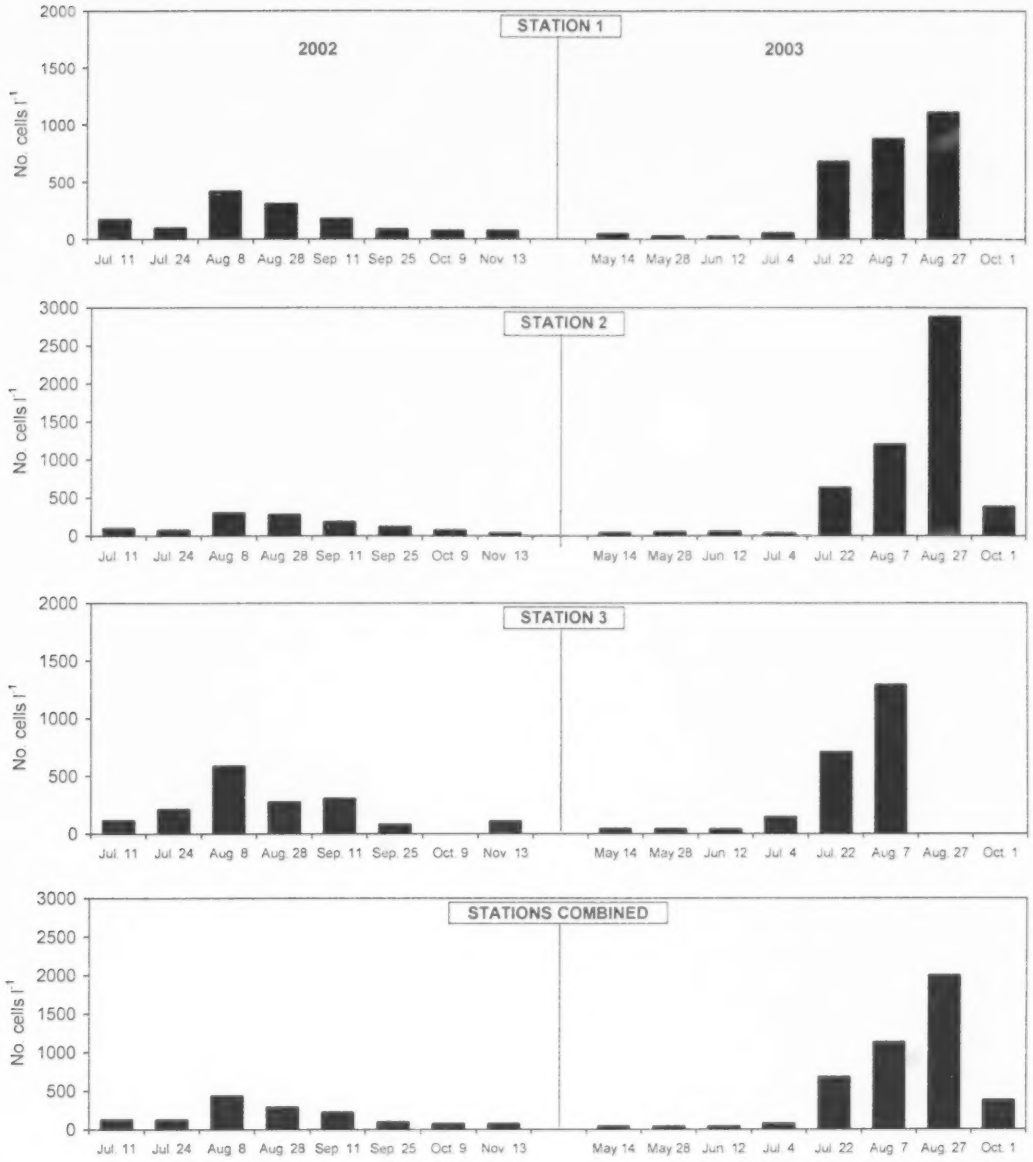

Figure 14. Seasonal distribution of *Asterionella formosa* (means of depths). See text for details on stations and depths sampled on a particular date.

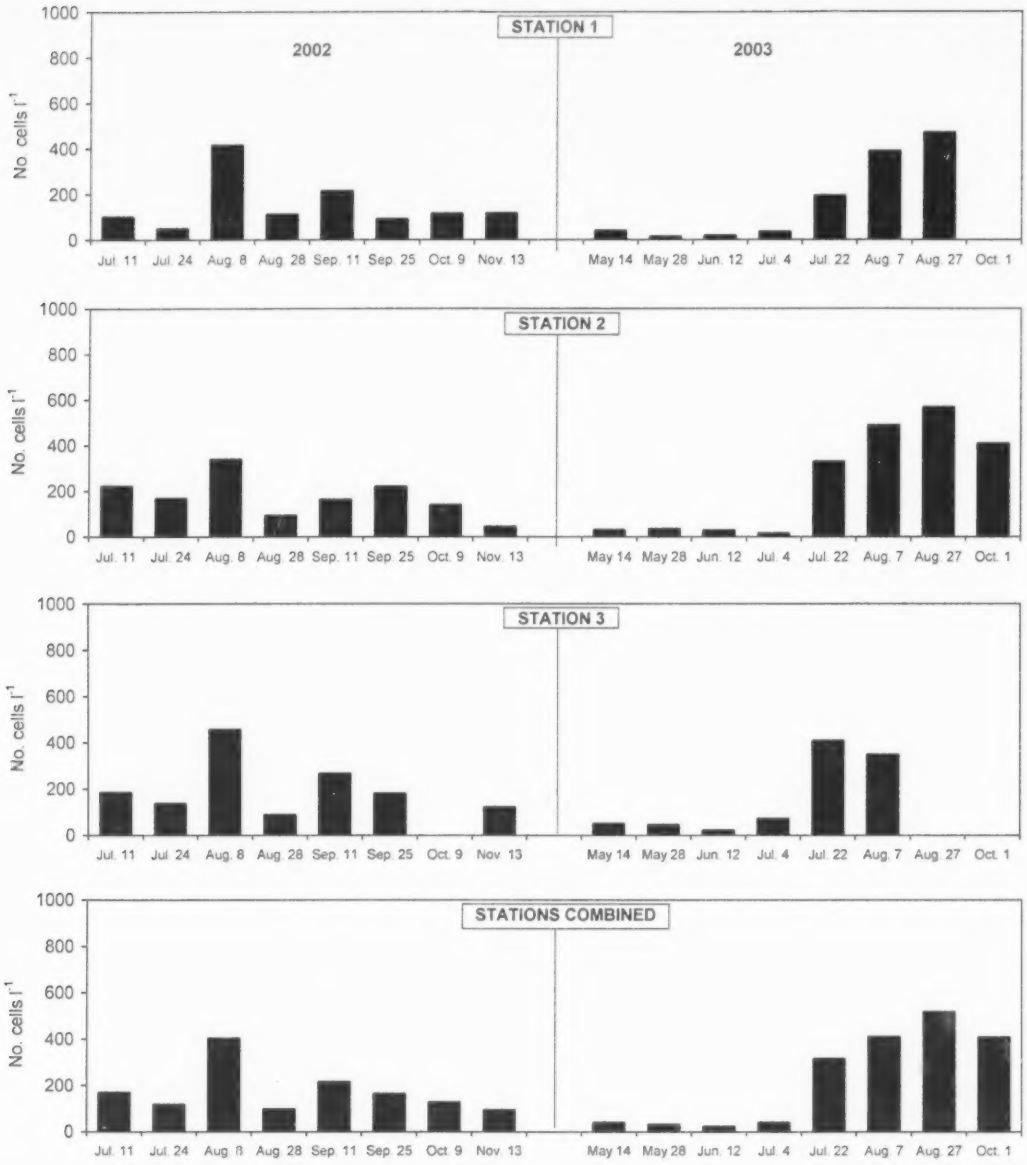

Figure 15. Seasonal distribution of *Tabellaria fenestrata* (means of depths). See text for details on stations and depths sampled on a particular date.

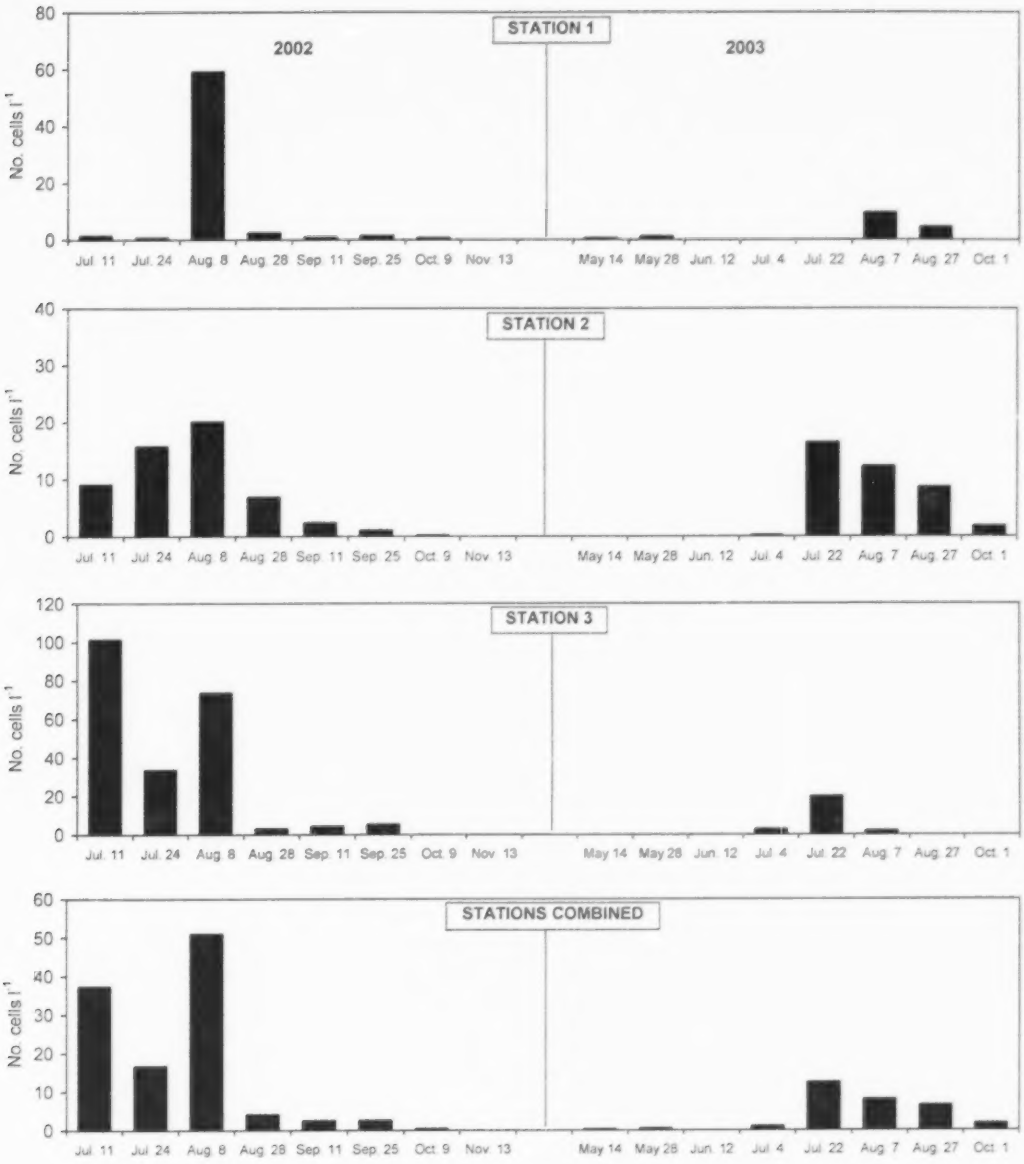

Figure 16. Seasonal distribution of *Tabellaria flocculosa* (means of depths). See text for details on stations and depths sampled on a particular date.

Figure 17. Vertical distribution of *Asterionella formosa* by station. See text for details on stations and depths sampled on a particular date.

Figure 18. Vertical distribution of *Tabellaria fenestrata* by station. See text for details on stations and depths sampled on a particular date.

Figure 19. Vertical distribution of *Tabellaria flocculosa* by station. See text for details on stations and depths sampled on a particular date.

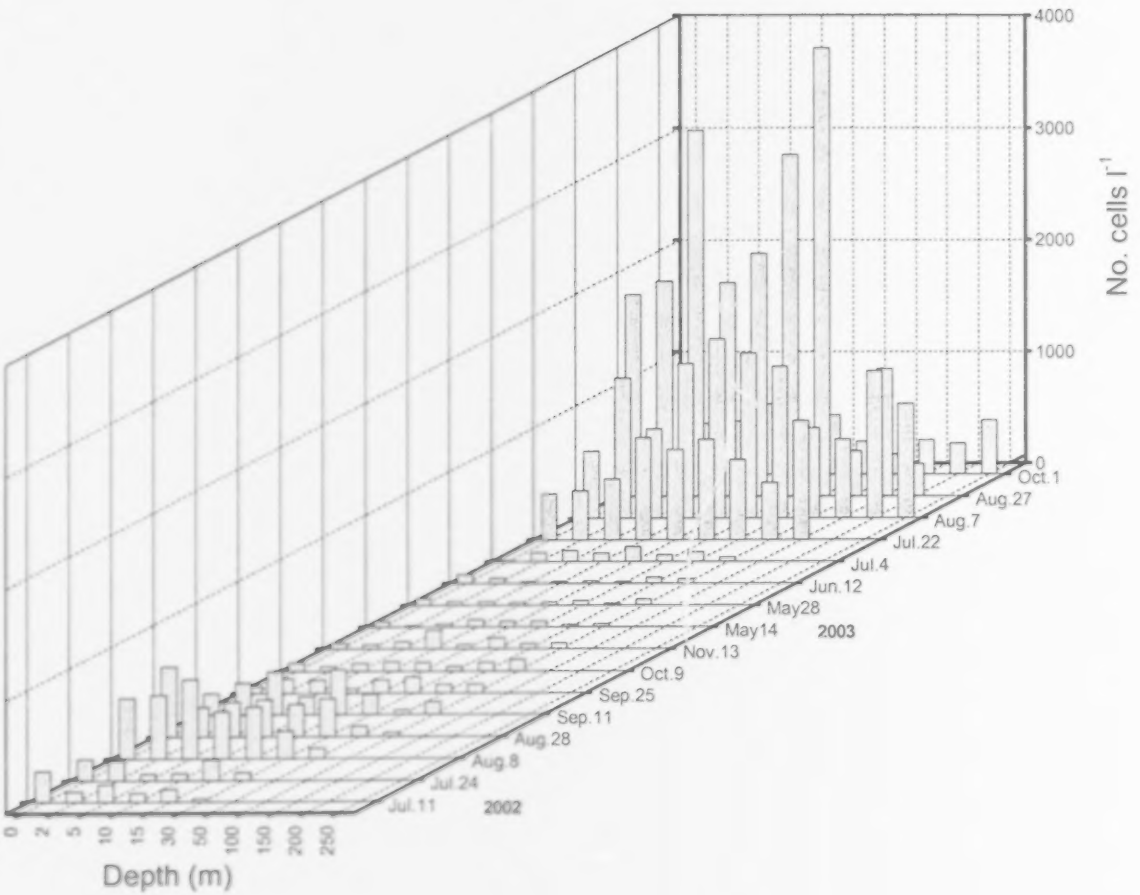

Figure 20. Vertical distribution of *Asterionella formosa* (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

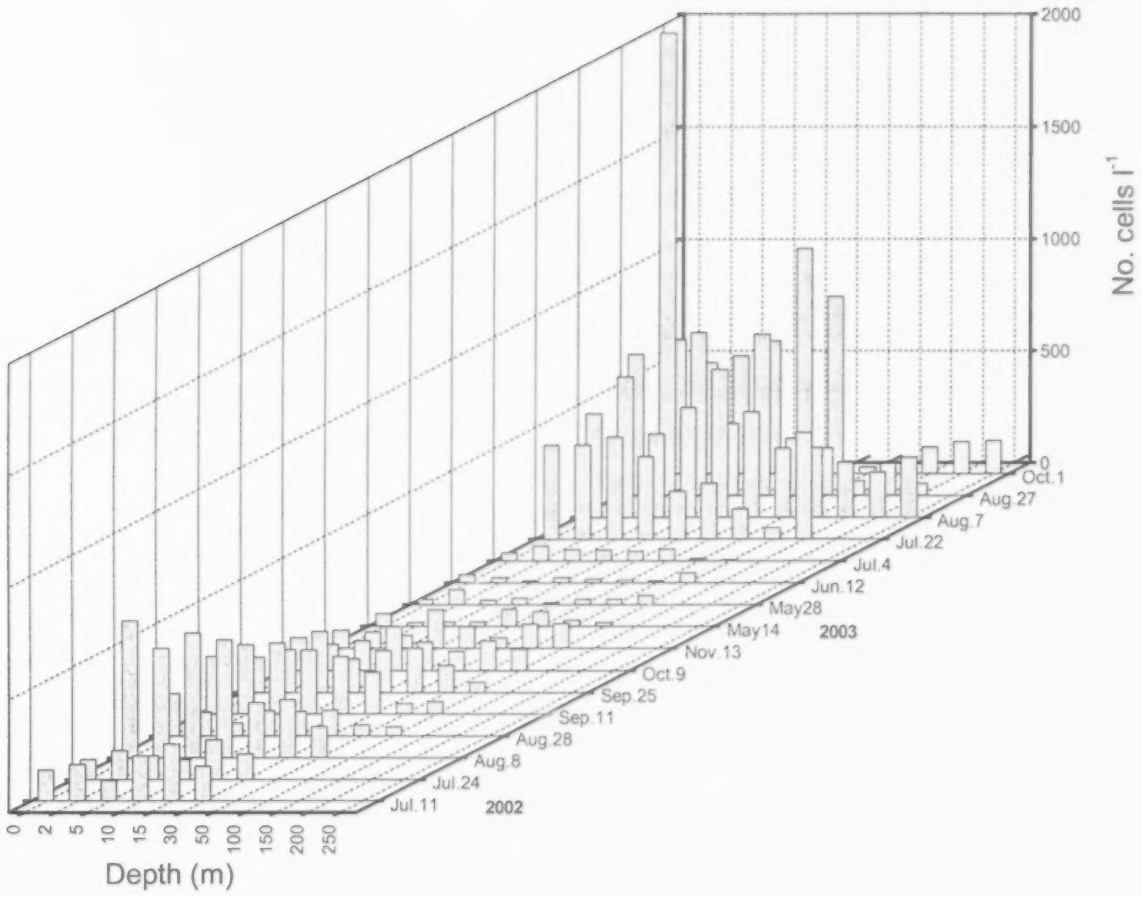

Figure 21. Vertical distribution of *Tabellaria fenestrata* (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

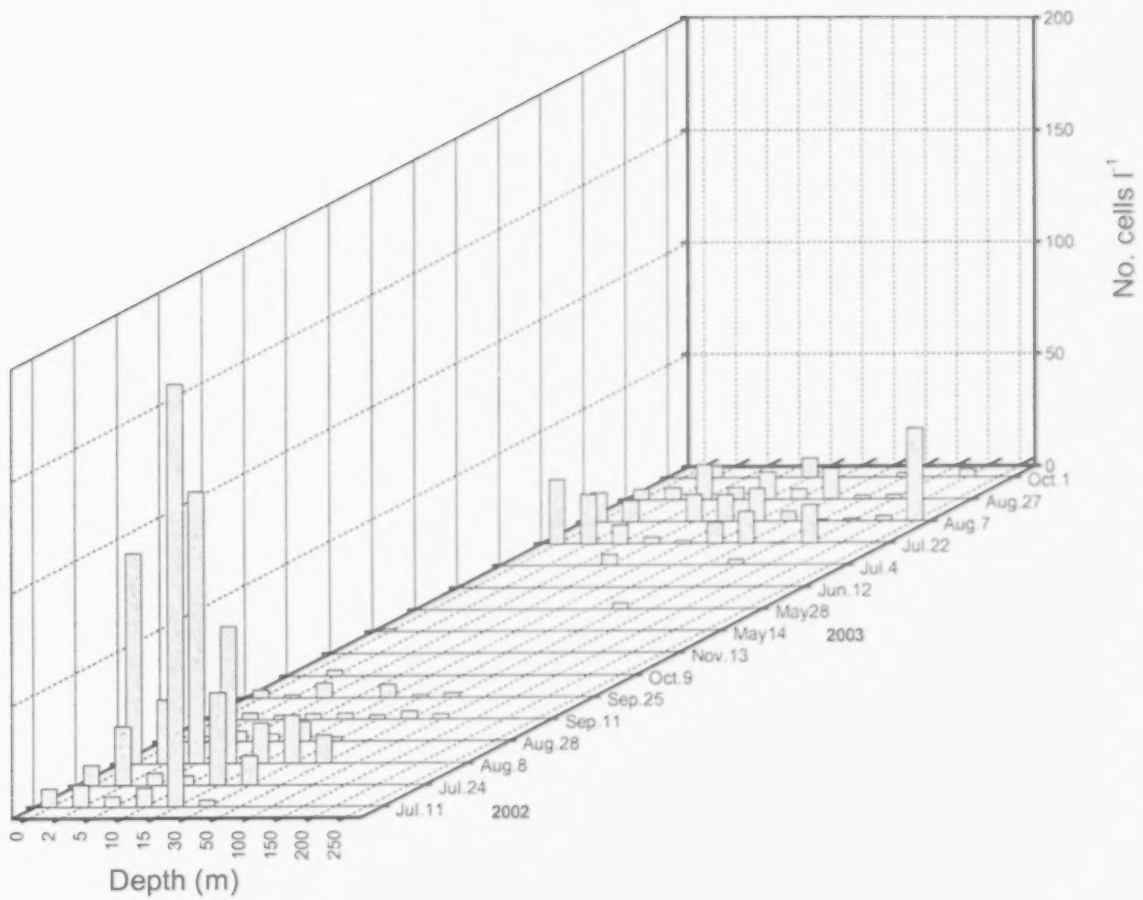

Figure 22. Vertical distribution of *Tabellaria flocculosa* (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

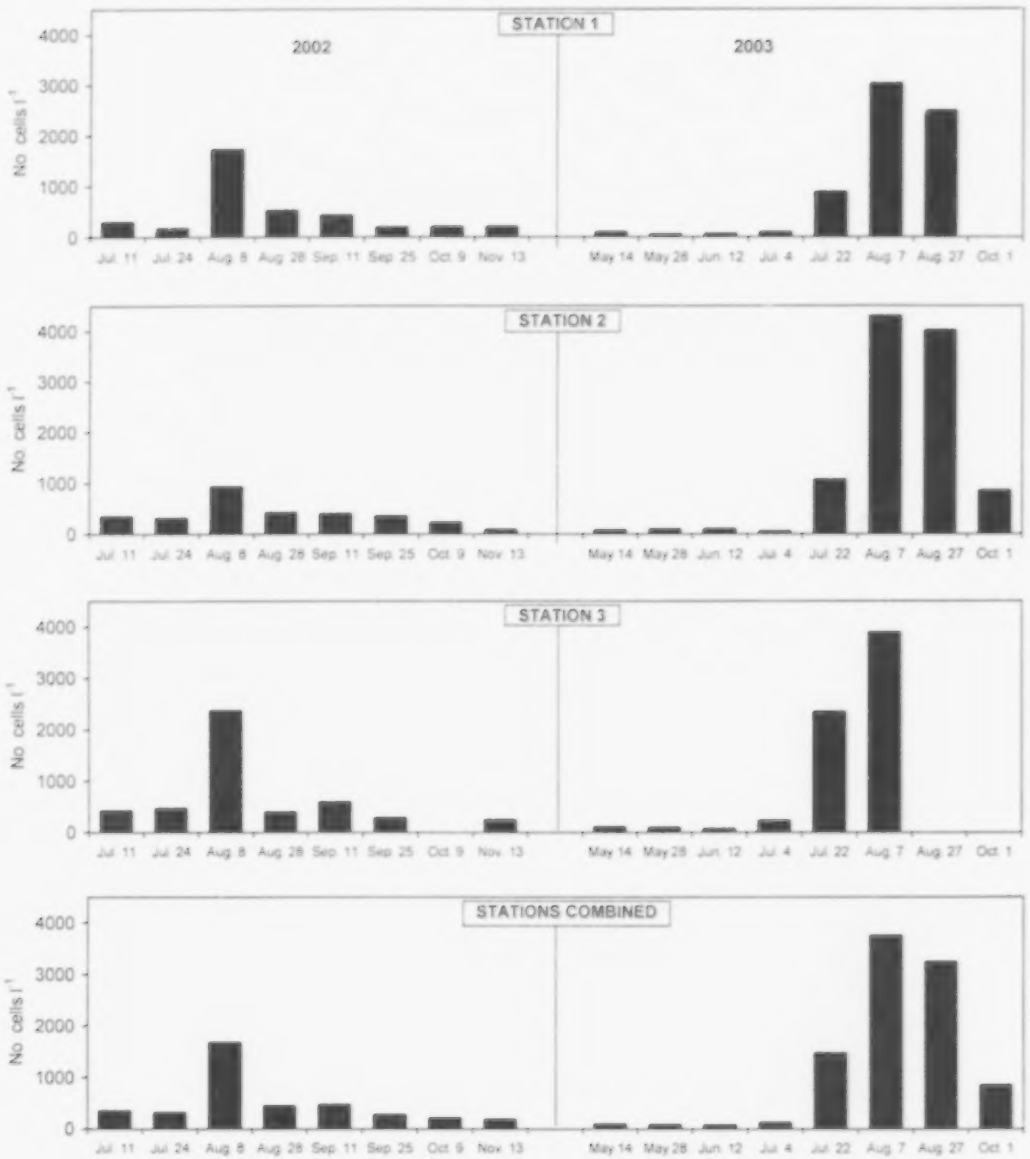

Figure 23. Seasonal distribution of total net phytoplankton (means of depths). See text for details on stations and depths sampled on a particular date.

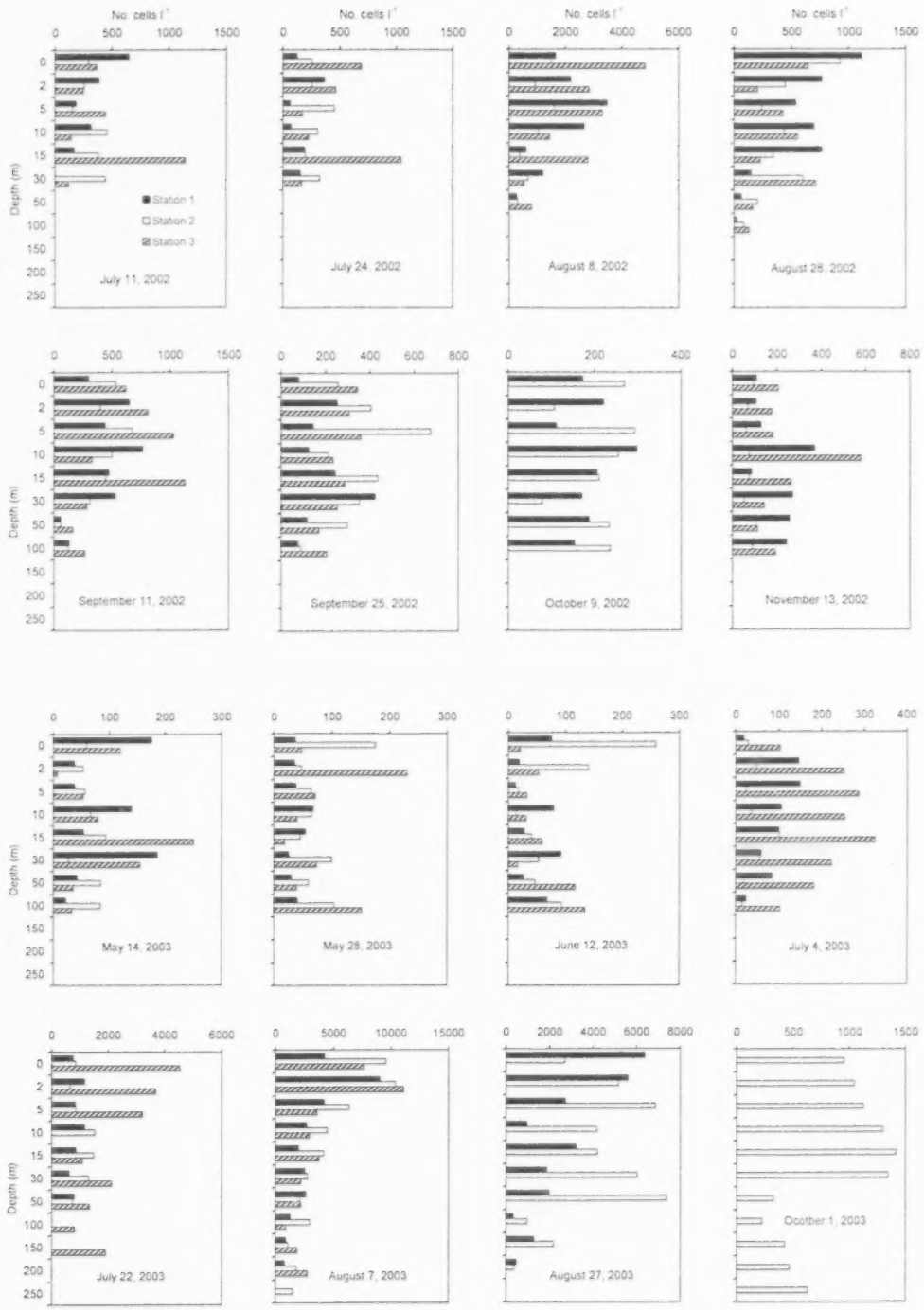

Figure 24. Vertical distribution of total net phytoplankton by station. See text for details on stations and depths sampled on a particular date.

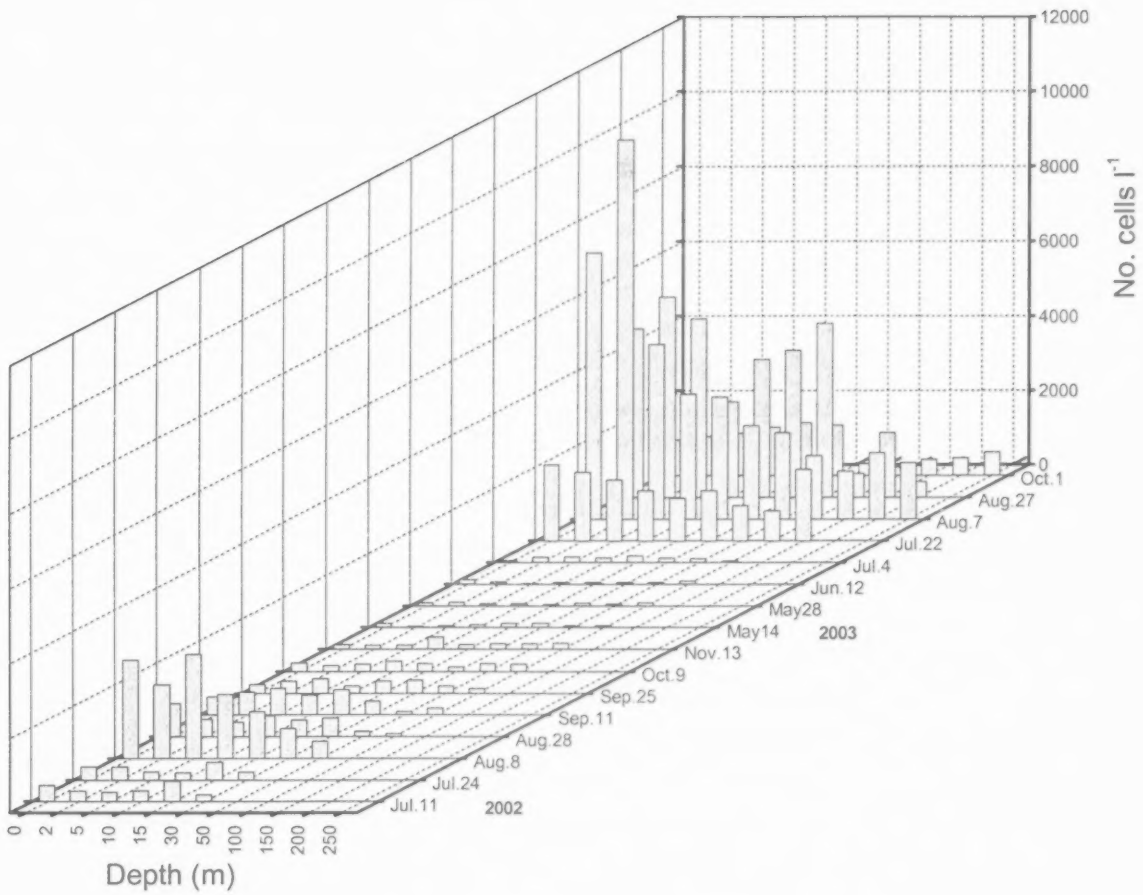

Figure 25. Vertical distribution of total net phytoplankton (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

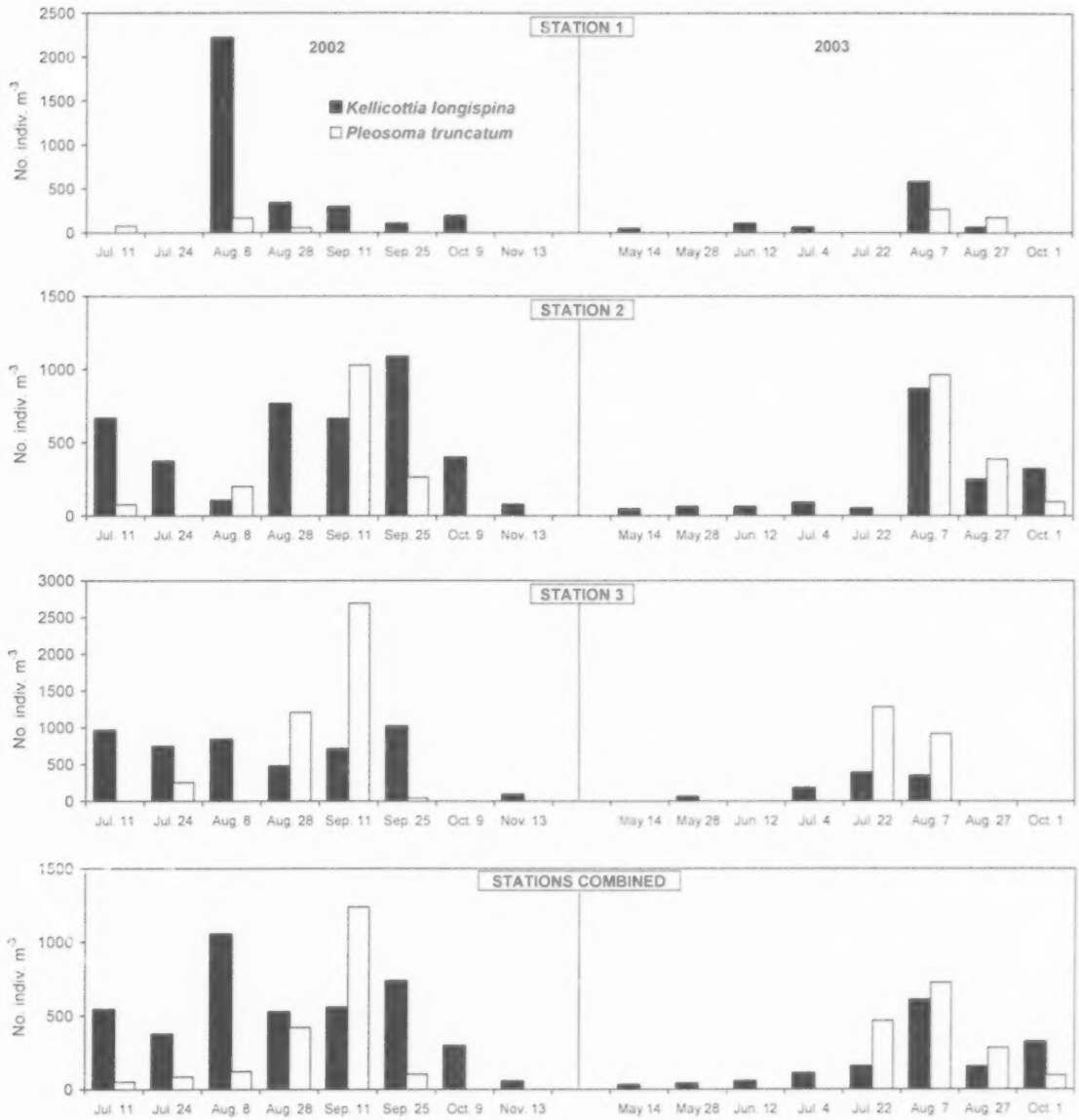

Figure 26. Seasonal distribution of *Kellicottia longispina* and *Pleosoma truncatum* (means of depths). See text for details on stations and depths sampled on a particular date.

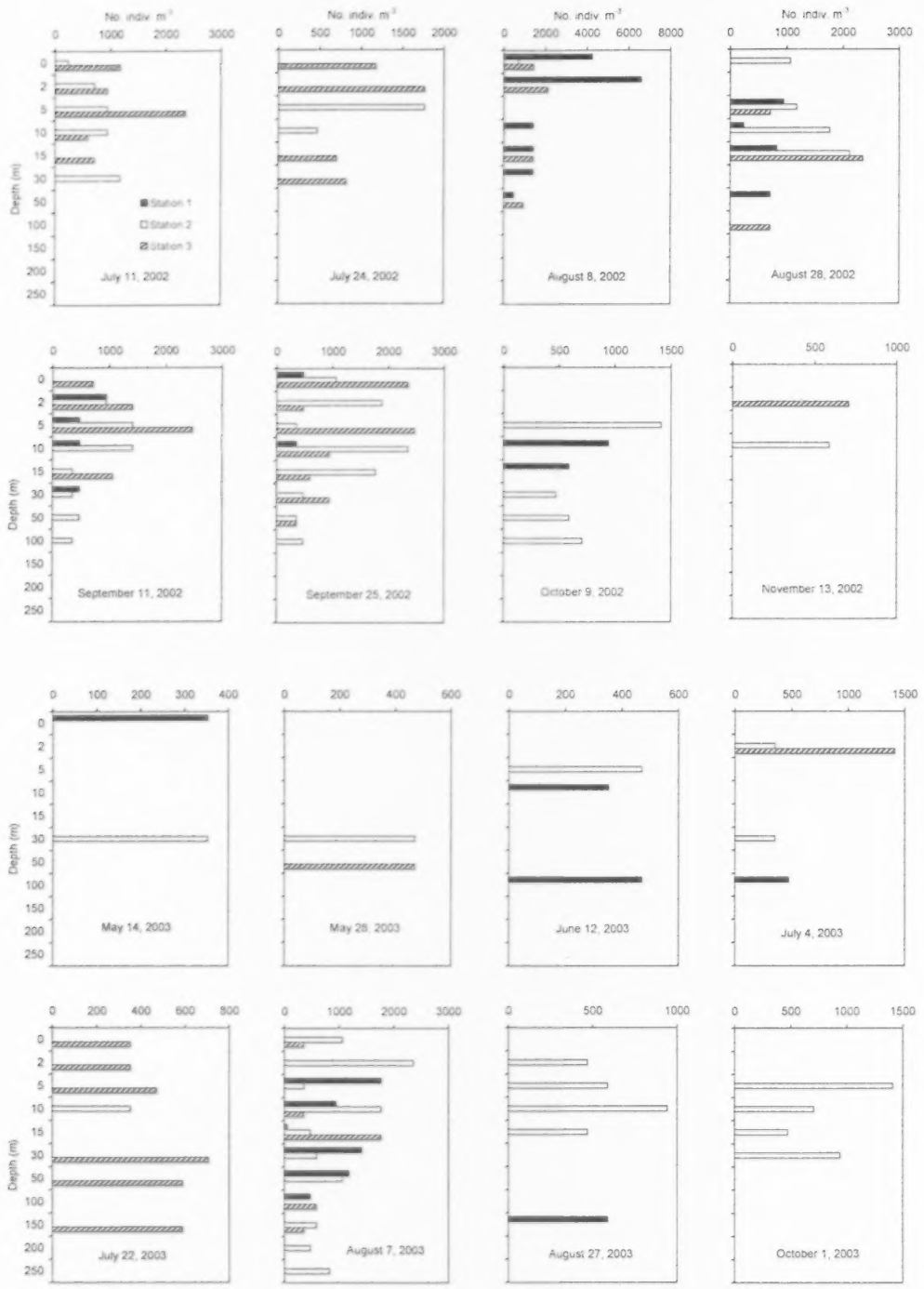

Figure 27. Vertical distribution of *Kellicottia lontgispina* by station. See text for details on stations and depths sampled on a particular date.

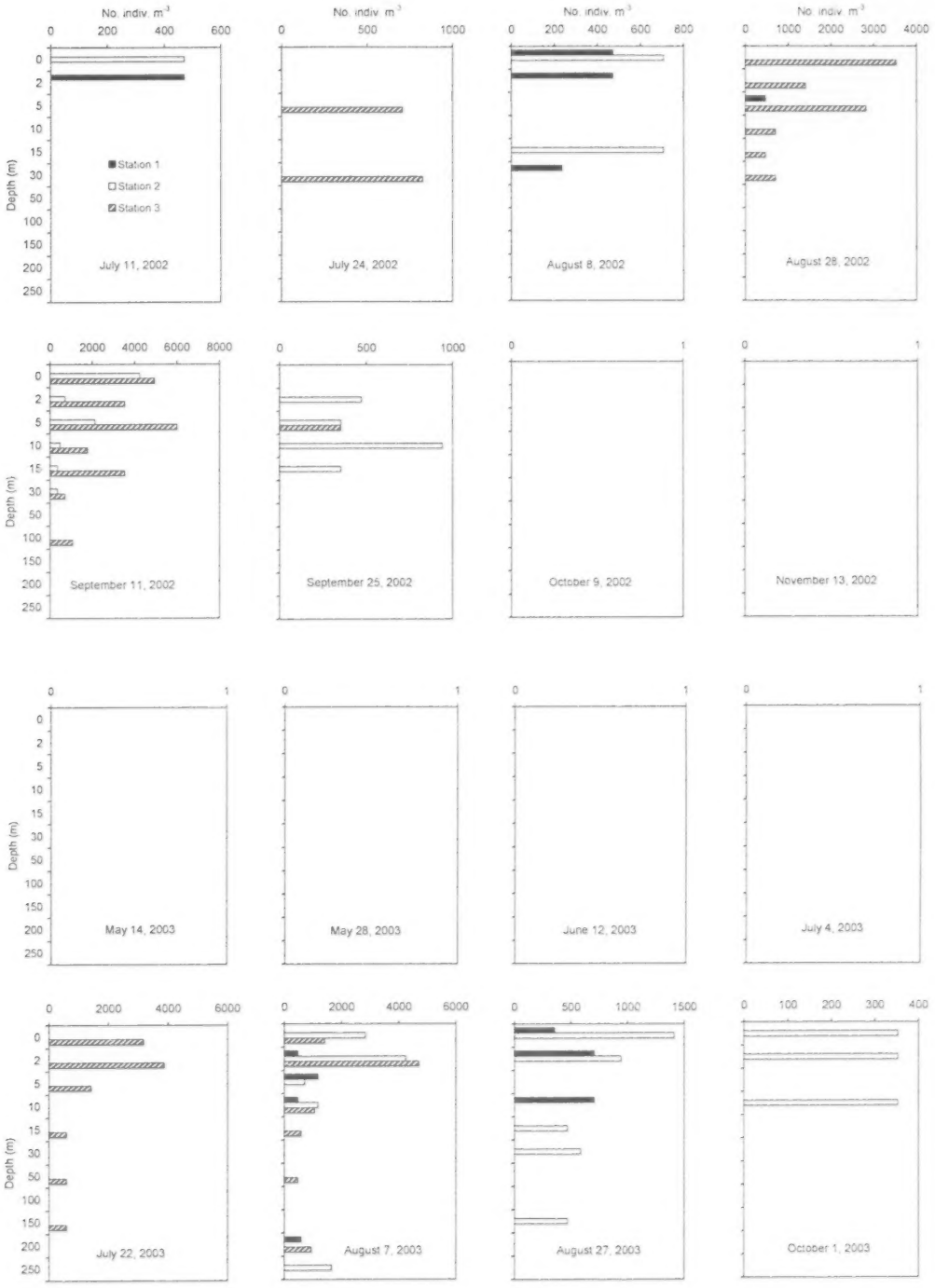

Figure 28. Vertical distribution of *Pleosoma truncatum* by station. See text for details on stations and depths sampled on a particular date.

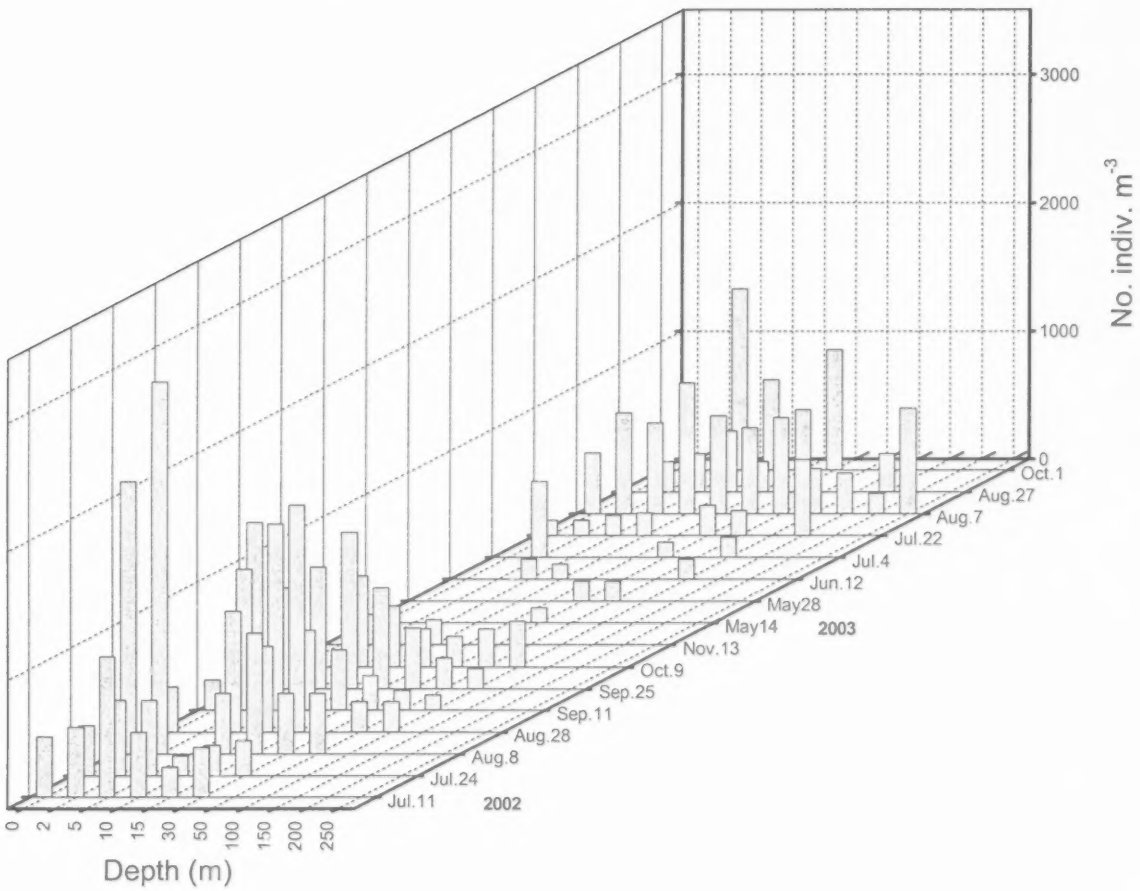

Figure 29. Vertical distribution of *Kellicottia longispina* (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

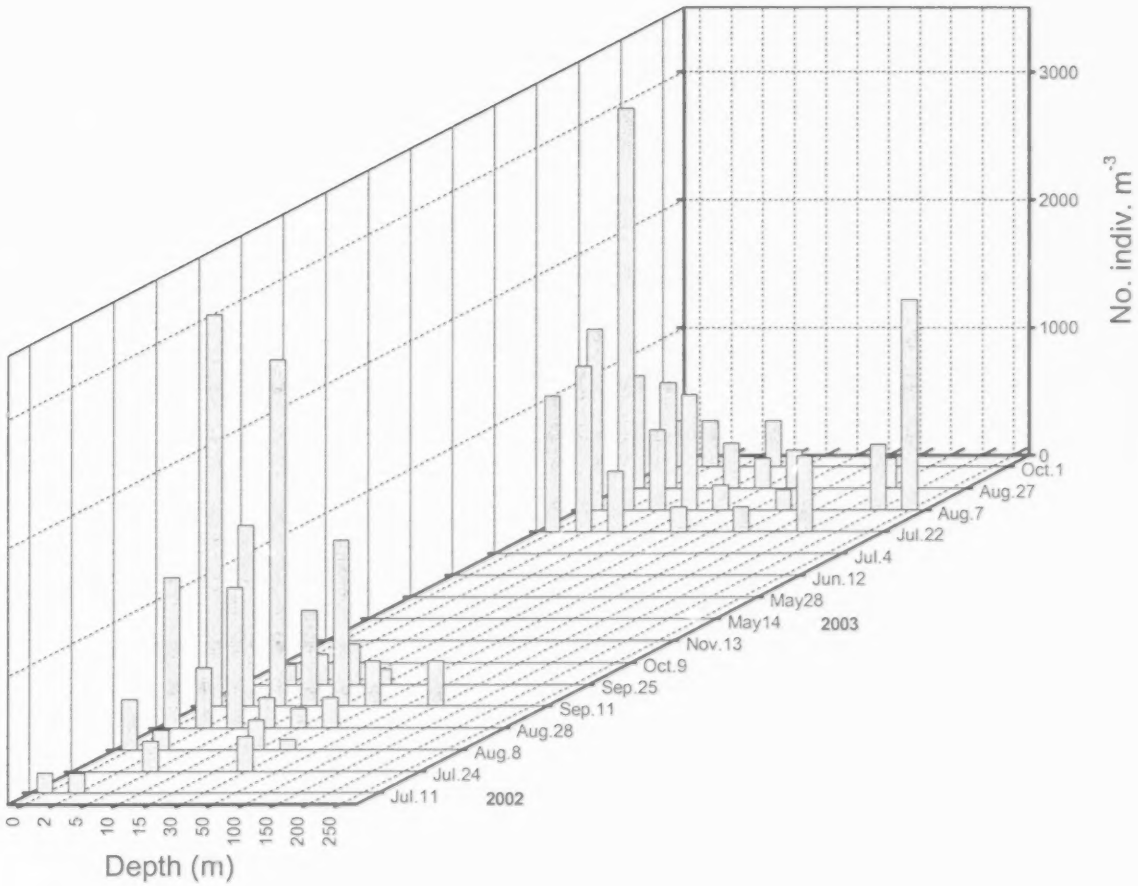

Figure 30. Vertical distribution of *Pleosoma truncatum* (means of stations) each sampling occasion. See text for details on stations and depths sampled on a particular date.

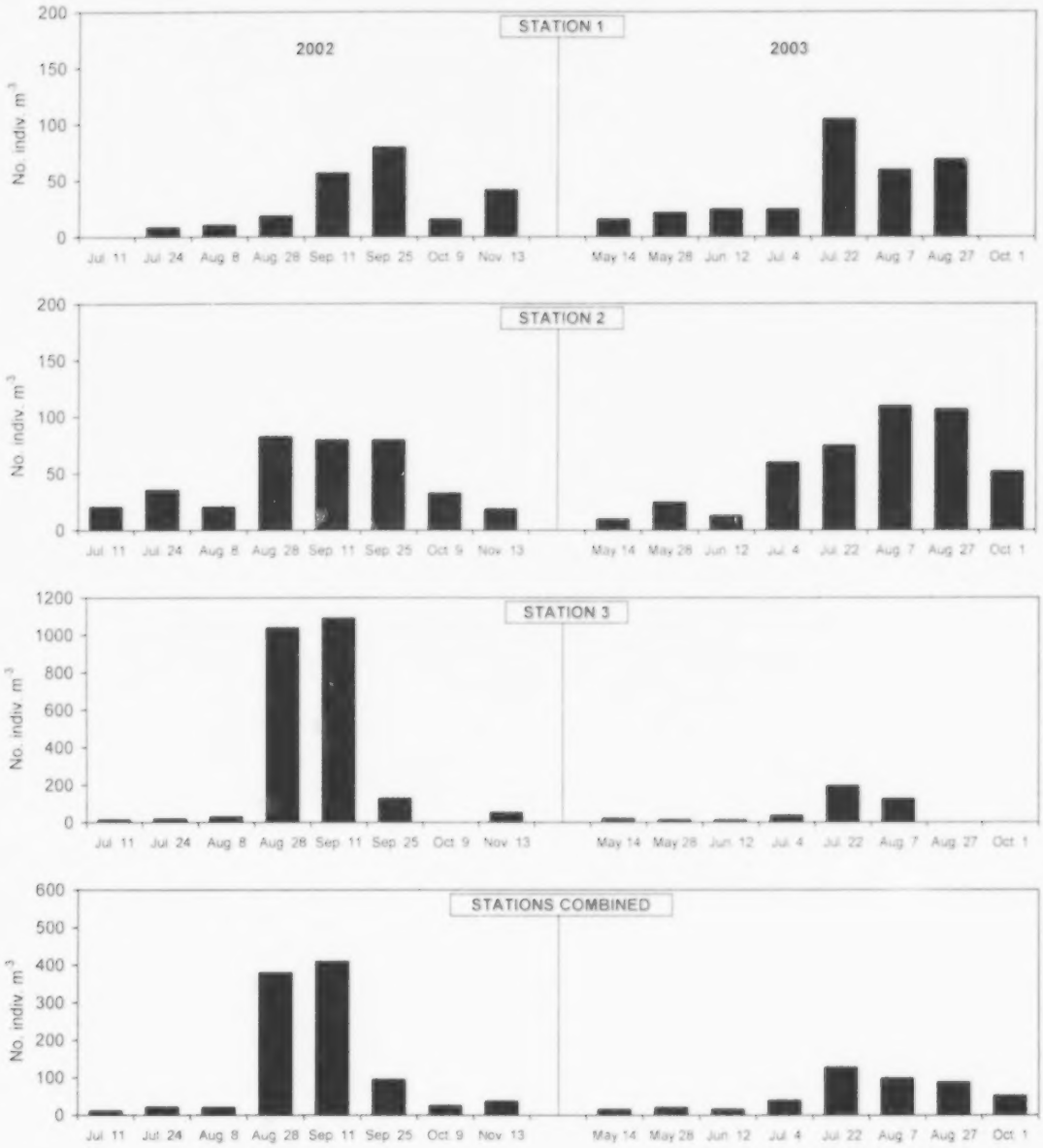

Figure 31. Seasonal distribution of Bosminidae (*Eubosmina longispina* and *Bosmina longirostris* combined) (means of depths). Data are for adults and juveniles combined. See text for details on stations and depths sampled on a particular date.

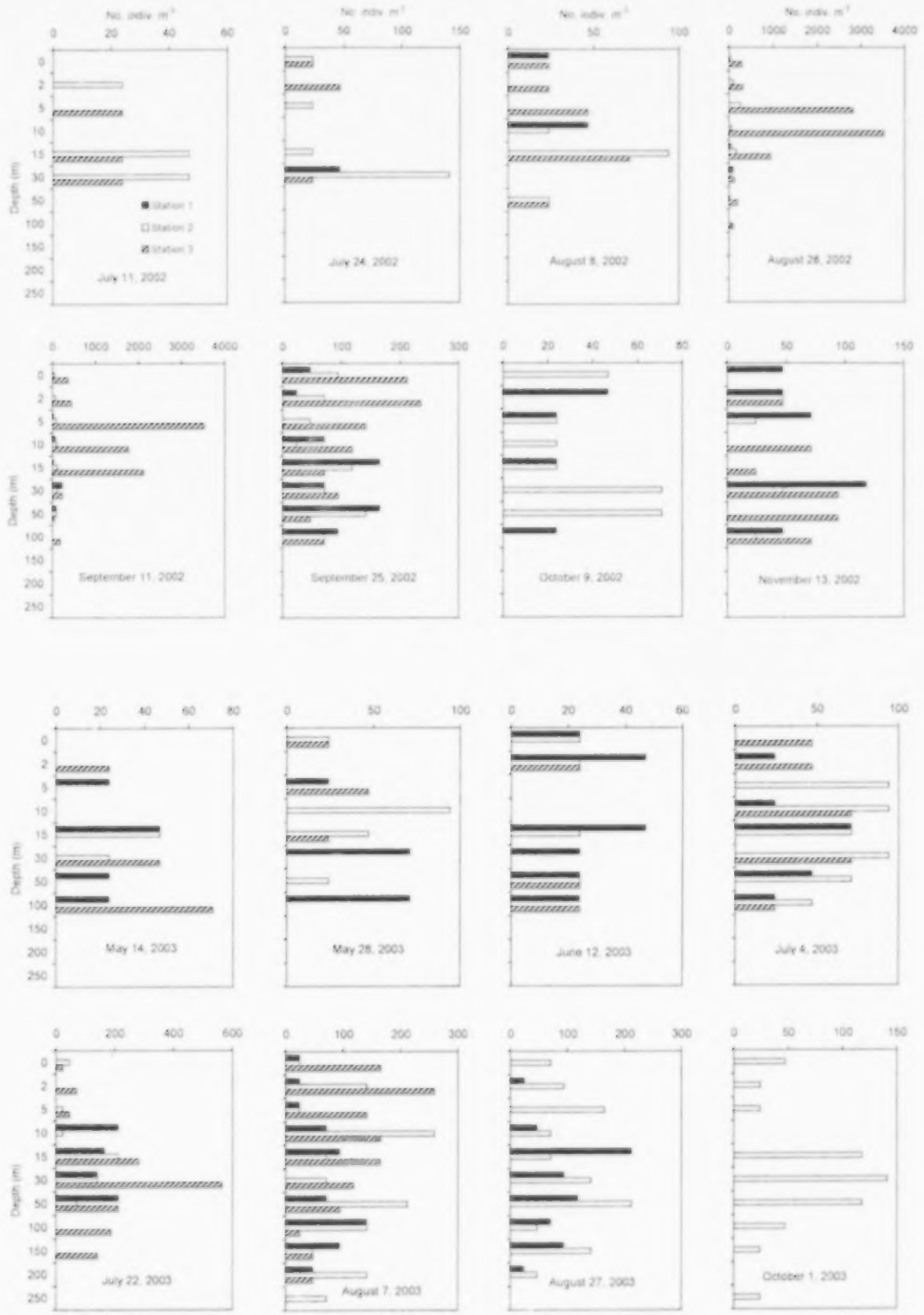

Figure 32. Vertical distribution of Bosminidae (data for *Eubosmina longispina* and *Bosmina longirostris* combined) by station. Data are for adults and juveniles combined. See text for details on stations and depths sampled on a particular date.

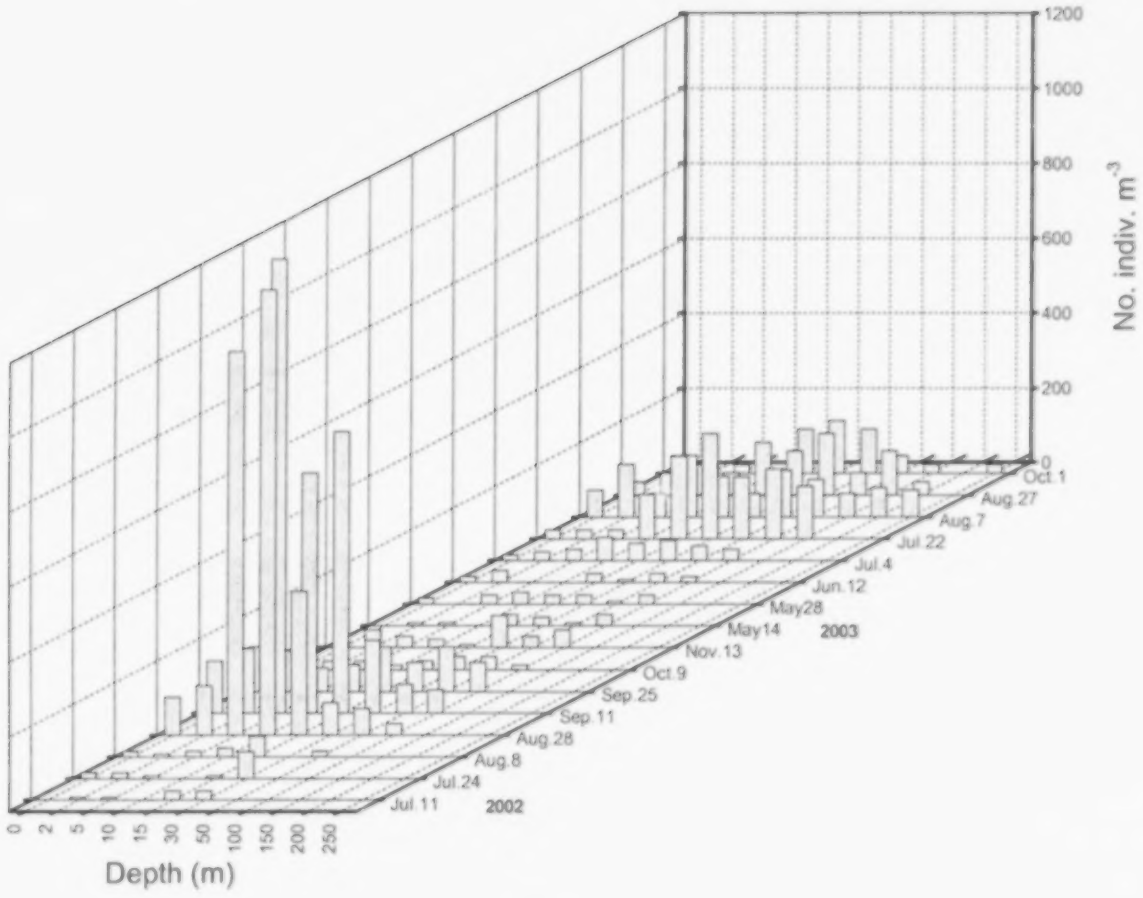

Figure 33. Vertical distribution of Bosminidae (data for *Eubosmina longispina* and *Bosmina longirostris* combined) for stations combined on each sampling occasion (means of stations). Data are for adults and juveniles combined. See text for details on stations and depths sampled on a particular date.

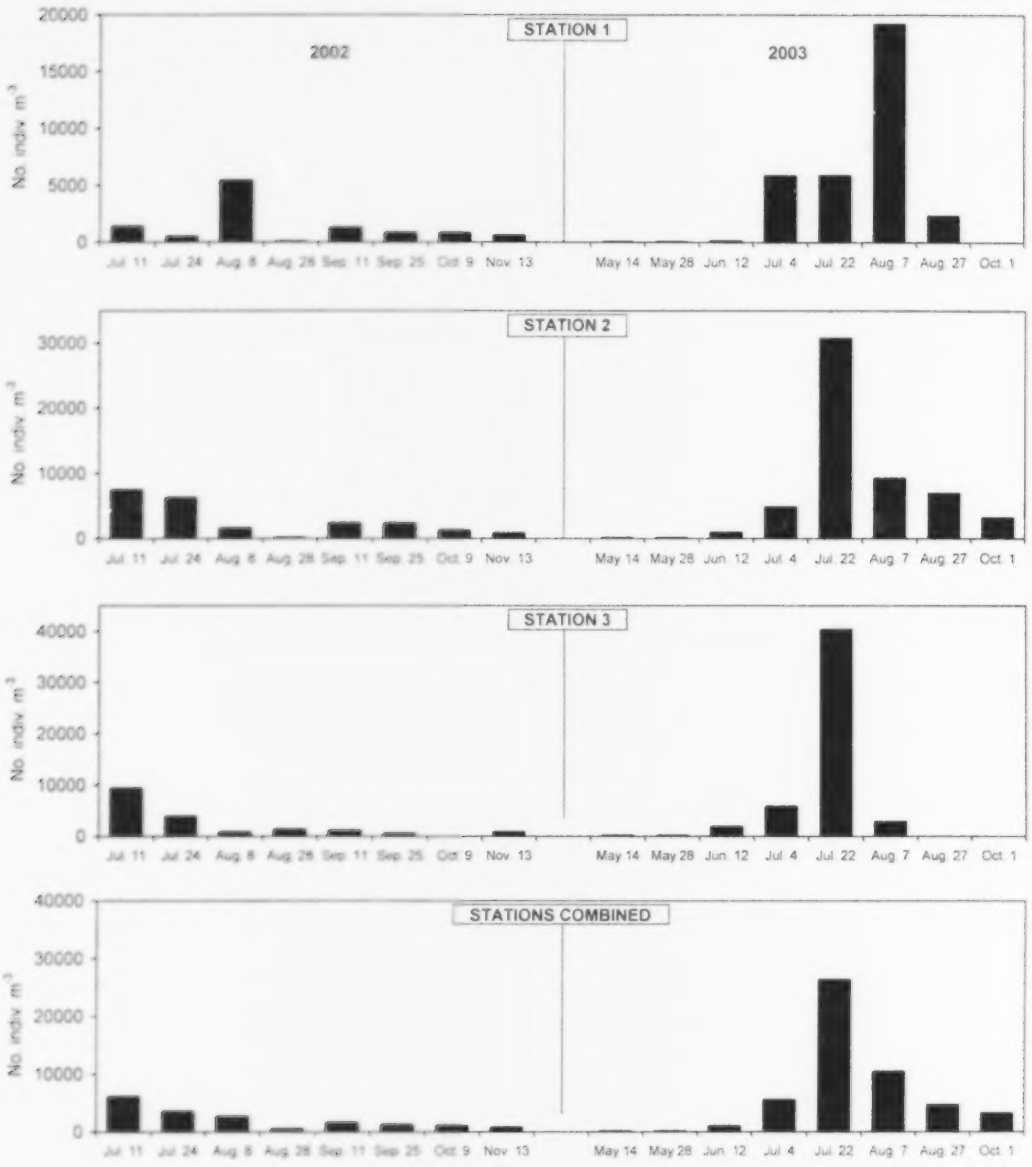

Figure 34. Seasonal distribution of copepod nauplii (means of depths). See text for details on stations and depths sampled on a particular date.

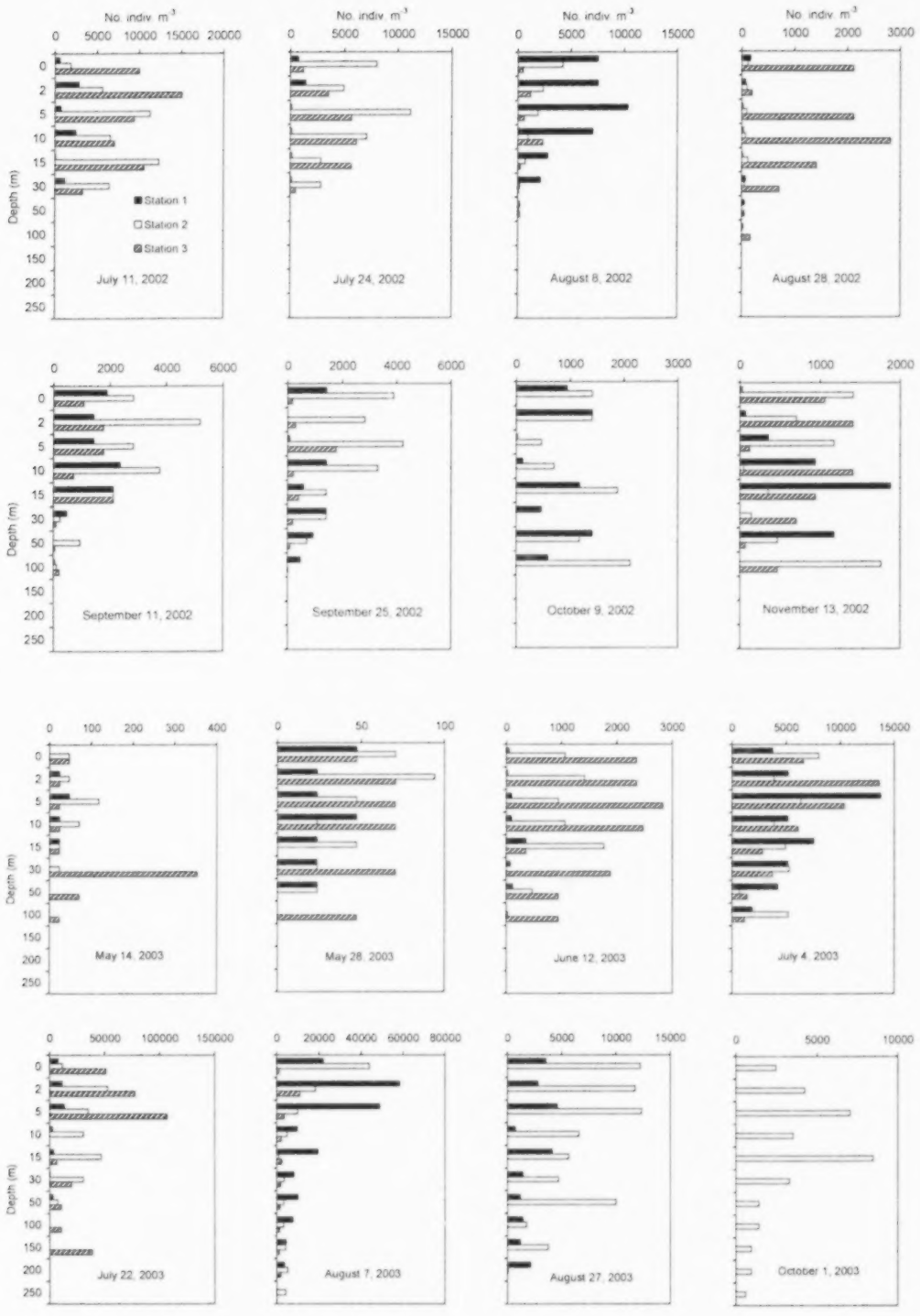

Figure 35. Vertical distribution of total copepod nauplii by station. See text for details on stations and depths sampled on a particular date.

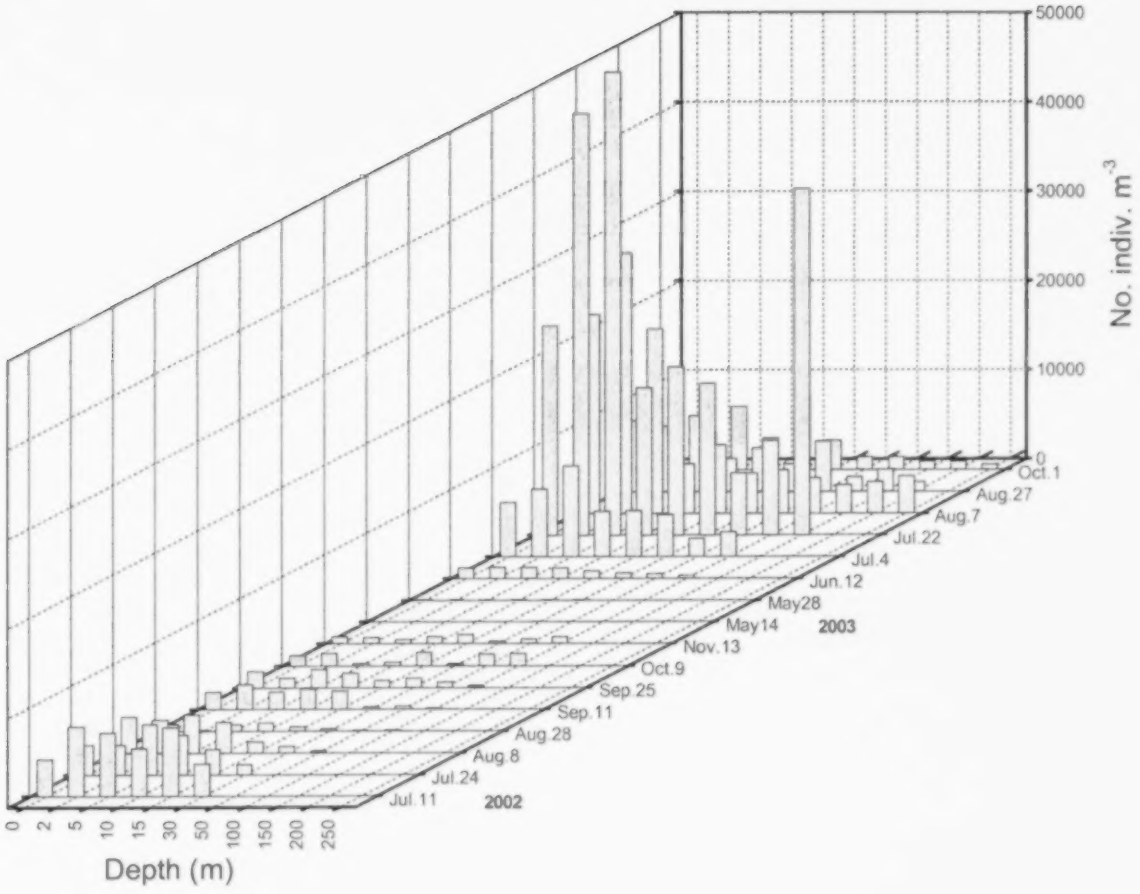

Figure 36. Vertical distribution of total copepod nauplii (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

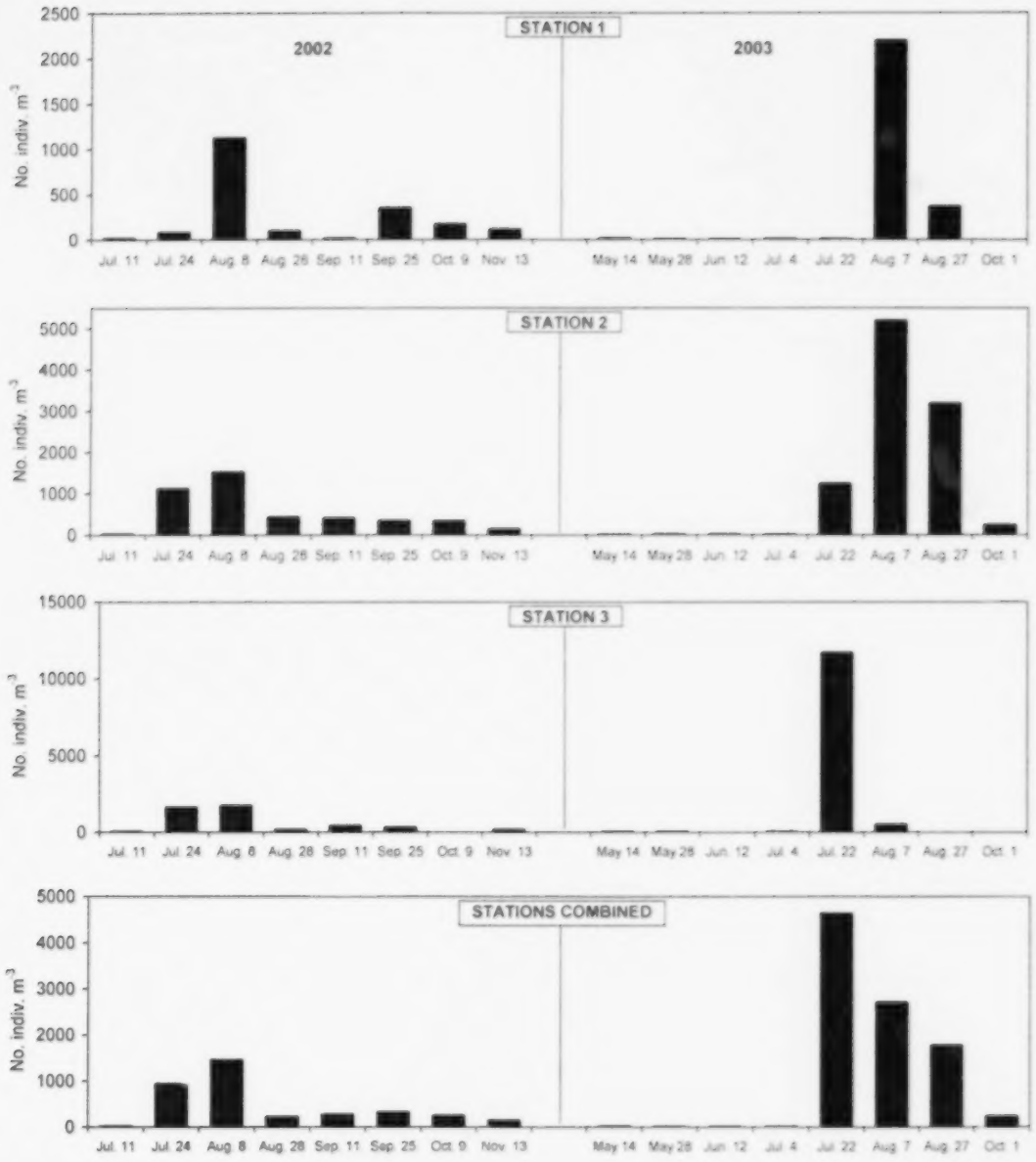
STATION 1
2002
2003
No. indiv. m-3
2500
2000
1500
1000
500
0
Jul. 11 Jul. 24 Aug. 8 Aug. 28 Sep. 11 Sep. 25 Oct. 9 Nov. 13
May 14 May 28 Jun. 12 Jul. 4 Jul. 22 Aug. 7 Aug. 27 Oct. 1
STATION 2
No. indiv. m-3
5000
4000
3000
2000
1000
0
Jul. 11 Jul. 24 Aug. 8 Aug. 28 Sep. 11 Sep. 25 Oct. 9 Nov. 13
May 14 May 28 Jun. 12 Jul. 4 Jul. 22 Aug. 7 Aug. 27 Oct. 1
STATION 3
No. indiv. m-3
15000
10000
5000
0
Jul. 11 Jul. 24 Aug. 8 Aug. 28 Sep. 11 Sep. 25 Oct. 9 Nov. 13
May 14 May 28 Jun. 12 Jul. 4 Jul. 22 Aug. 7 Aug. 27 Oct. 1
STATIONS COMBINED
No. indiv. m-3
5000
4000
3000
2000
1000
0
Jul. 11 Jul. 24 Aug. 8 Aug. 28 Sep. 11 Sep. 25 Oct. 9 Nov. 13
May 14 May 28 Jun. 12 Jul. 4 Jul. 22 Aug. 7 Aug. 27 Oct. 1

Figure 37. Seasonal distribution of diaptomid copepodites (means of depths). See text for details on stations and depths sampled on a particular date.

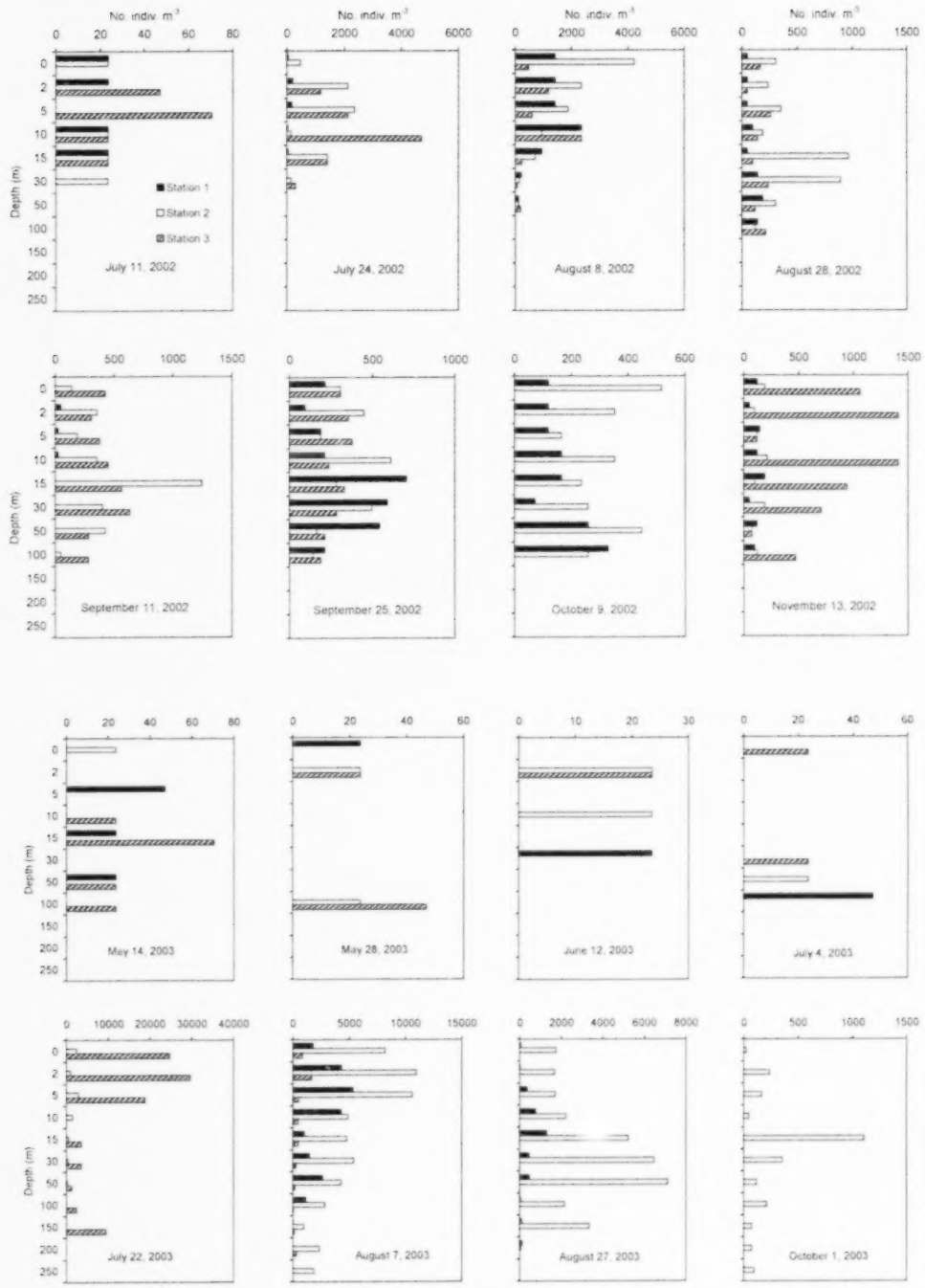

Figure 38. Vertical distribution of total diaptomid copepodites by station. See text for details on stations and depths sampled on a particular date.

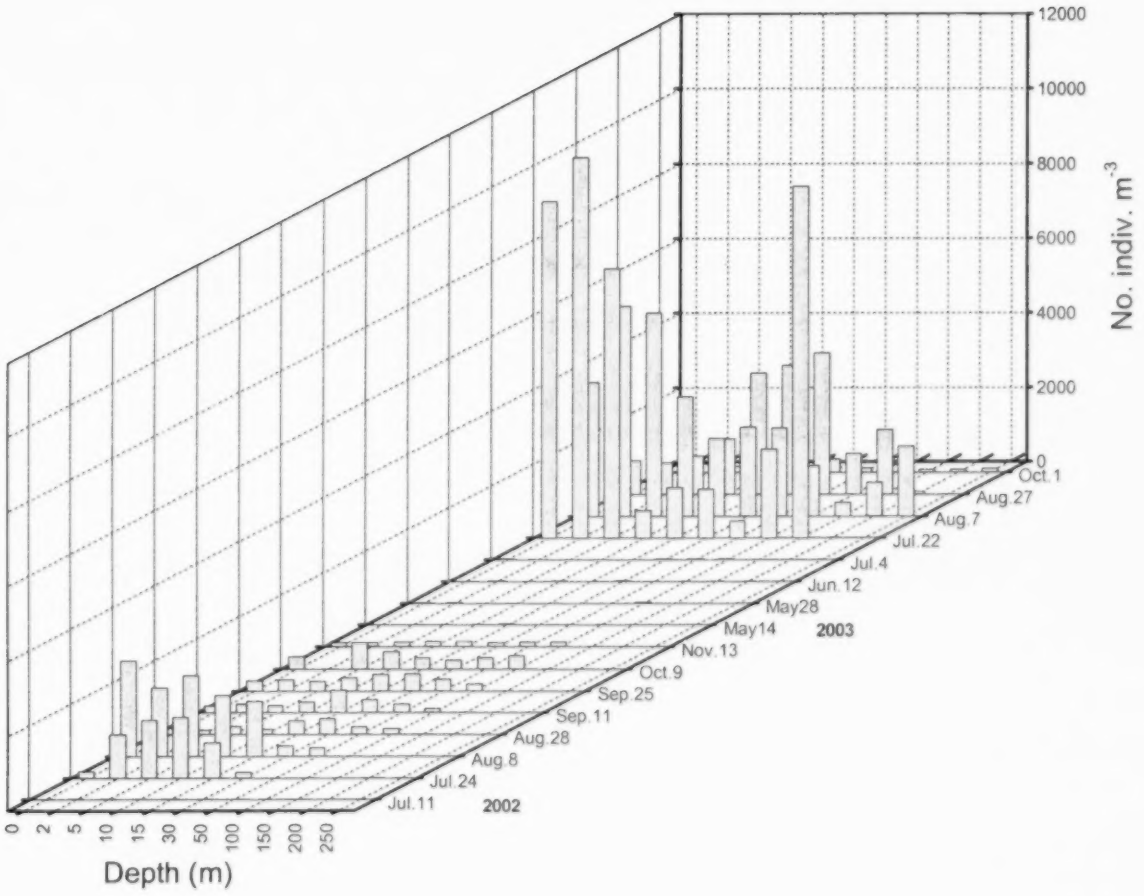

Figure 39. Vertical distribution of diaptomid copepodites (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

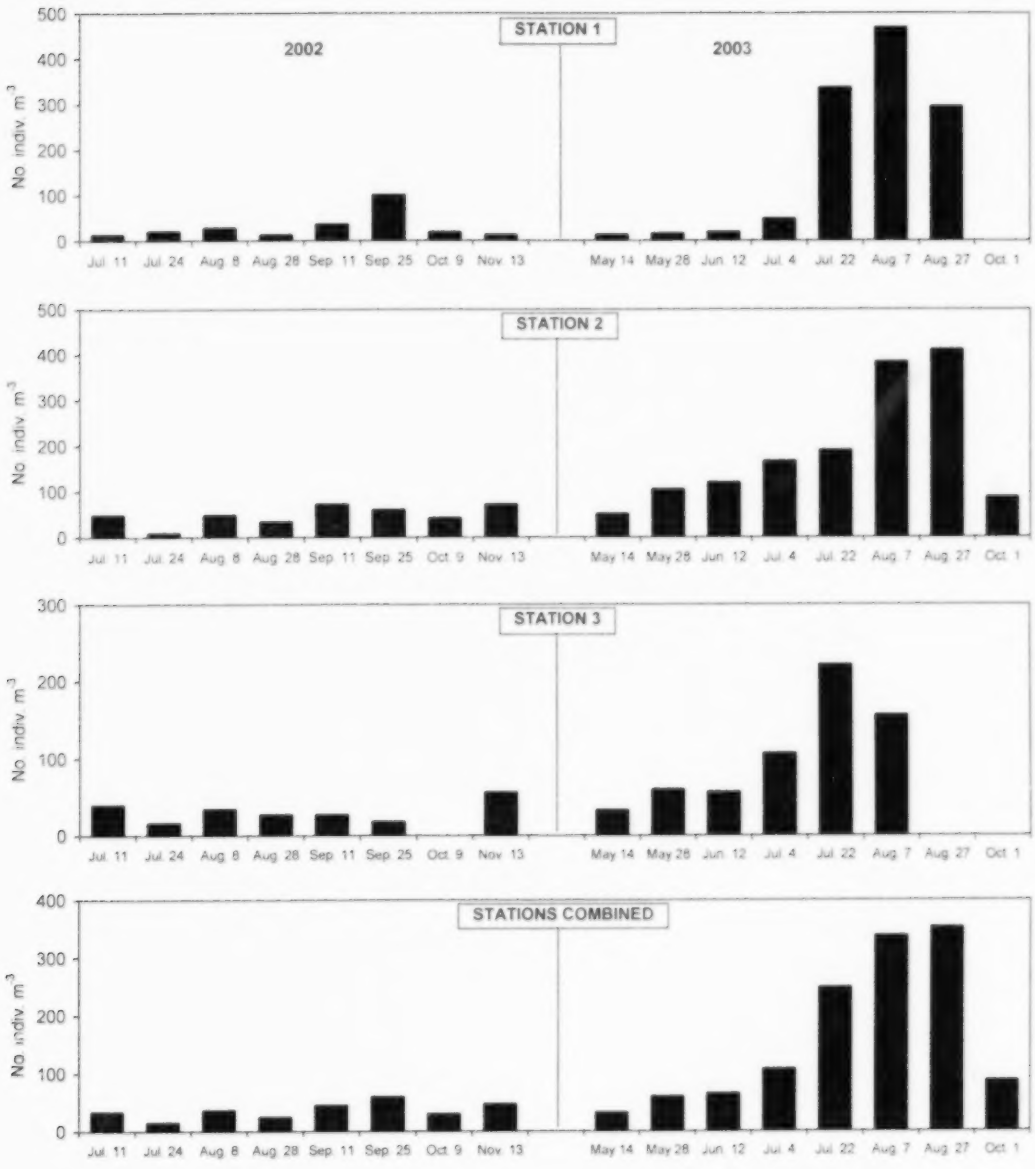

Figure 40. Seasonal distribution of *Leptodiaptomus minutus* adults (means of depths). See text for details on stations and depths sampled on a particular date.

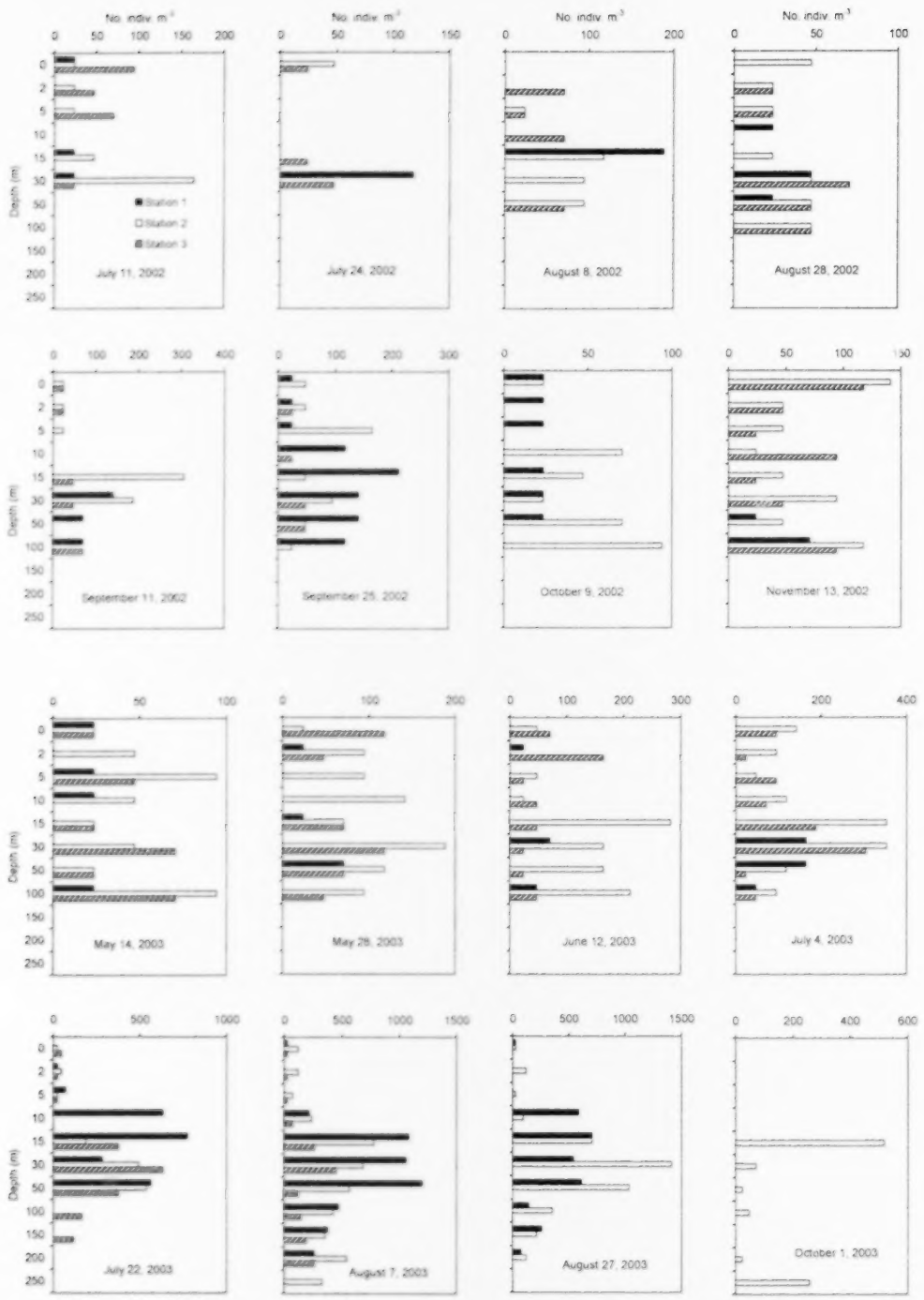

Figure 41. Vertical distribution of *Leptodiaptomus minutus* adults by station. See text for details on stations and depths sampled on a particular date.

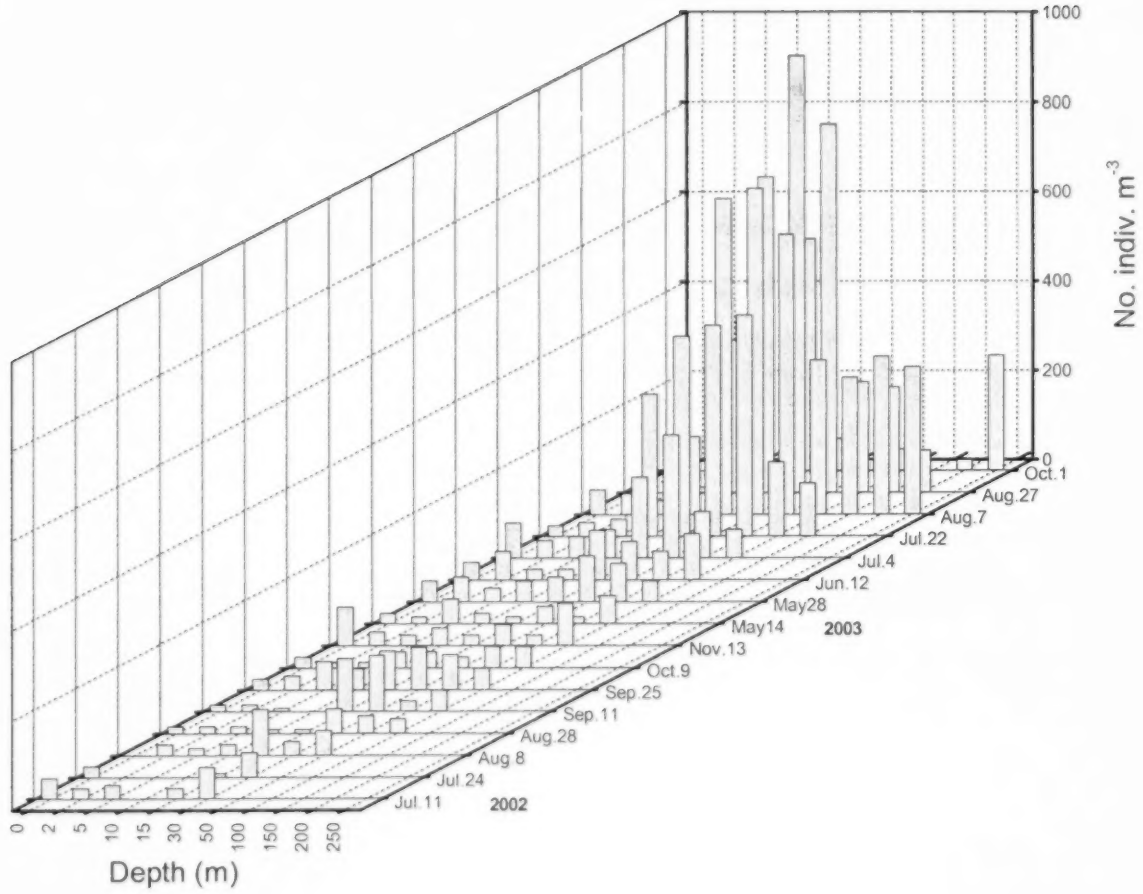

Figure 42. Vertical distribution of *Leptodiaptomus minutus* adults (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

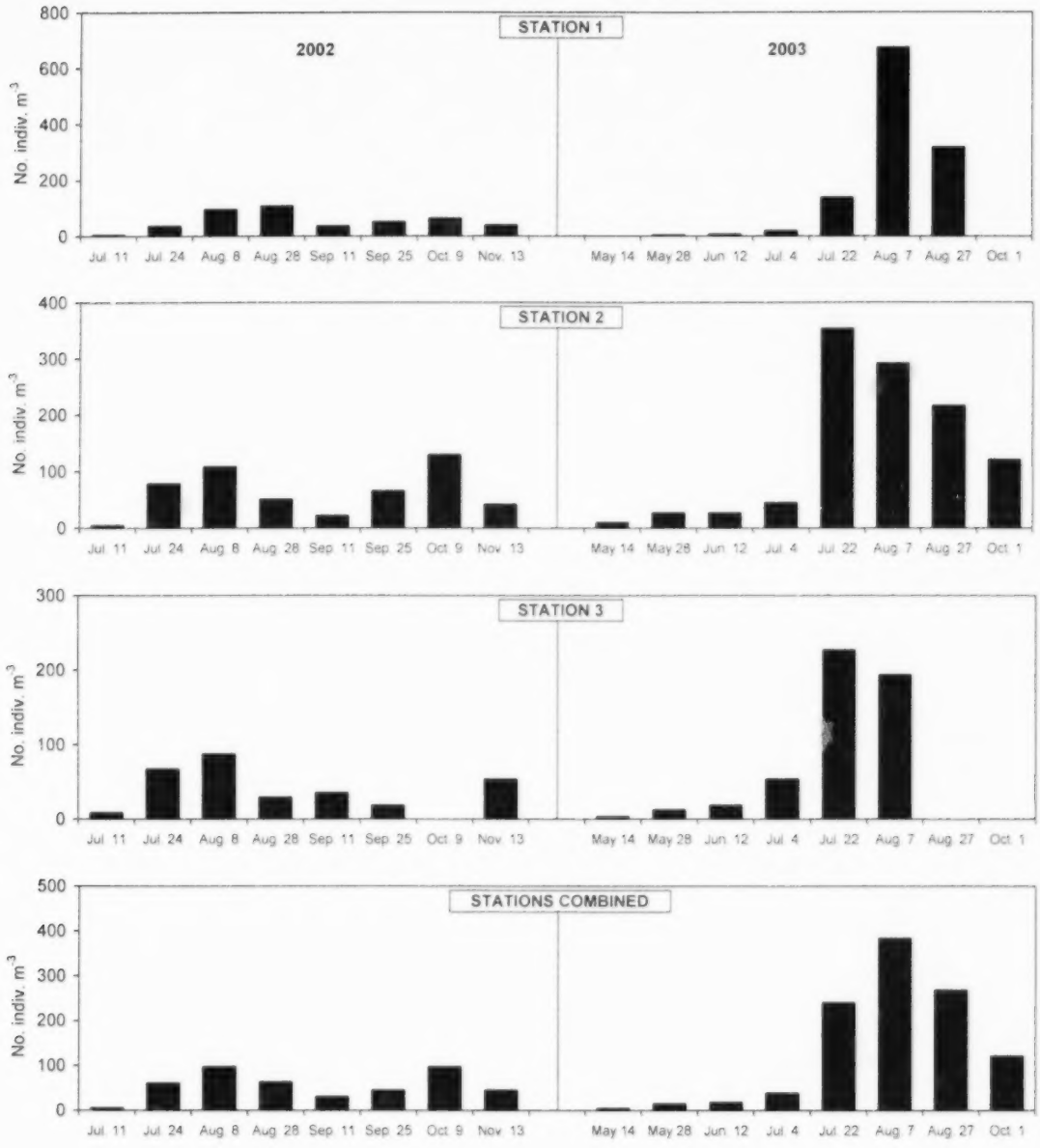

Figure 43. Seasonal distribution of cyclopoid copepodites (means of depths). See text for details on stations and depths sampled on a particular date.

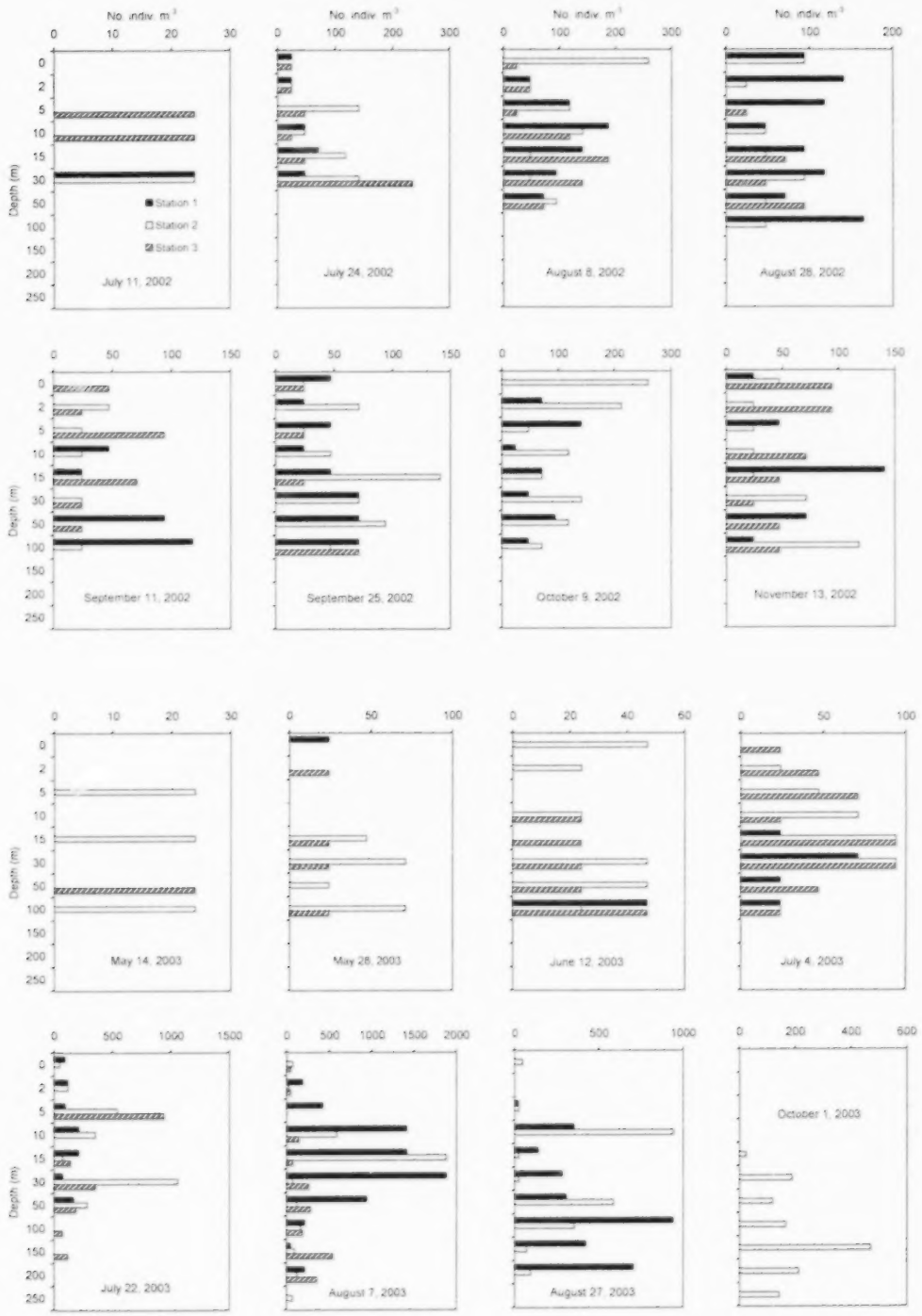

Figure 44. Vertical distribution of cyclopoid copepodites by station. See text for details on stations and depths sampled on a particular date.

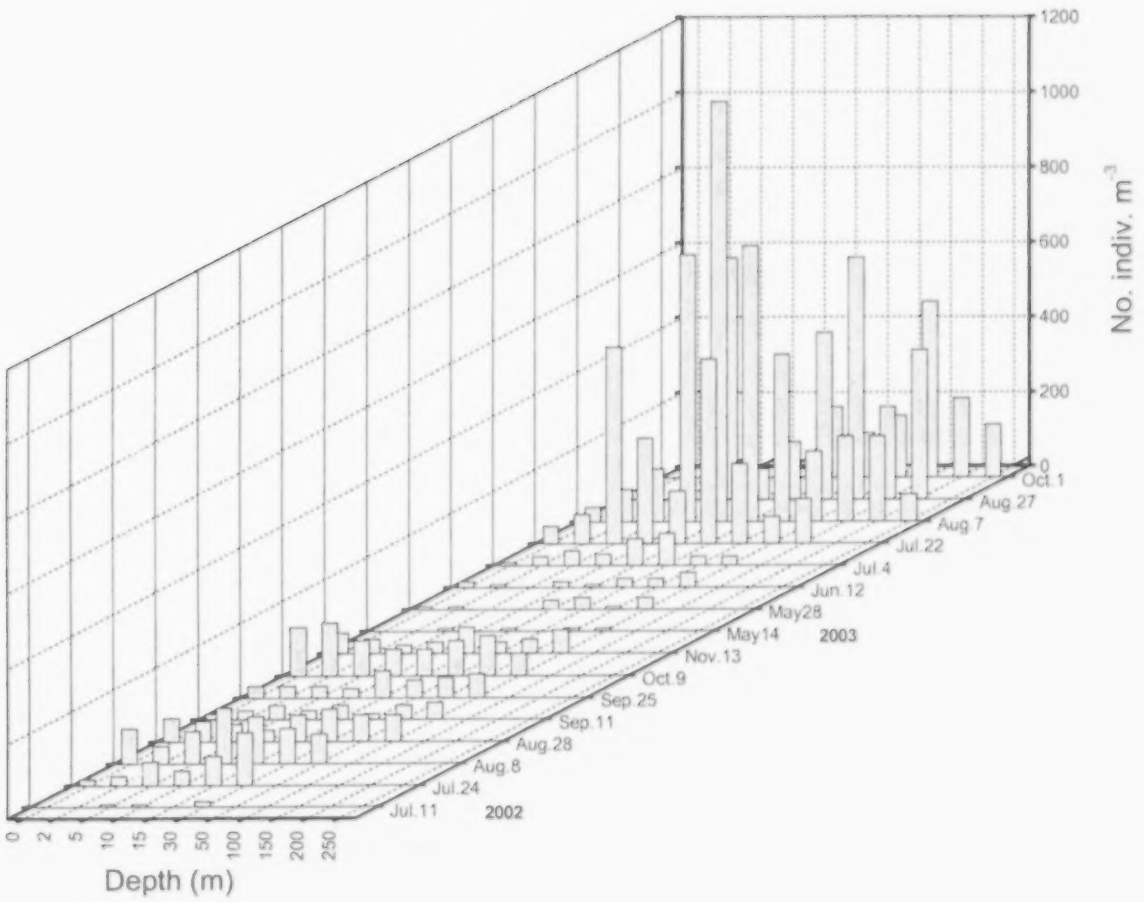

Figure 45. Vertical distribution of cyclopoid copepodites (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

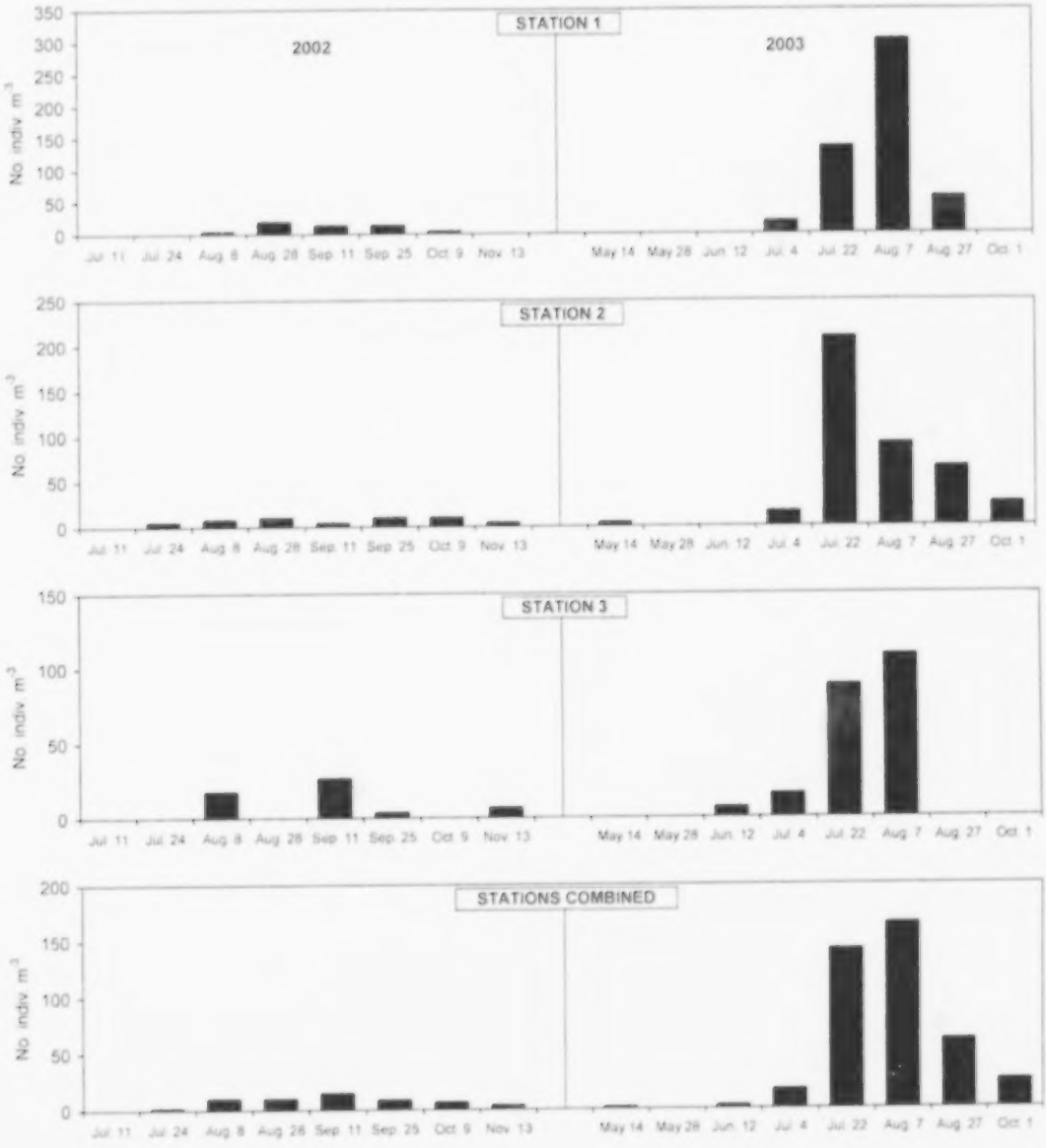

Figure 46. Seasonal distribution of *Cyclops scutifer* adults (means of depths). See text for details on stations and depths sampled on a particular date.

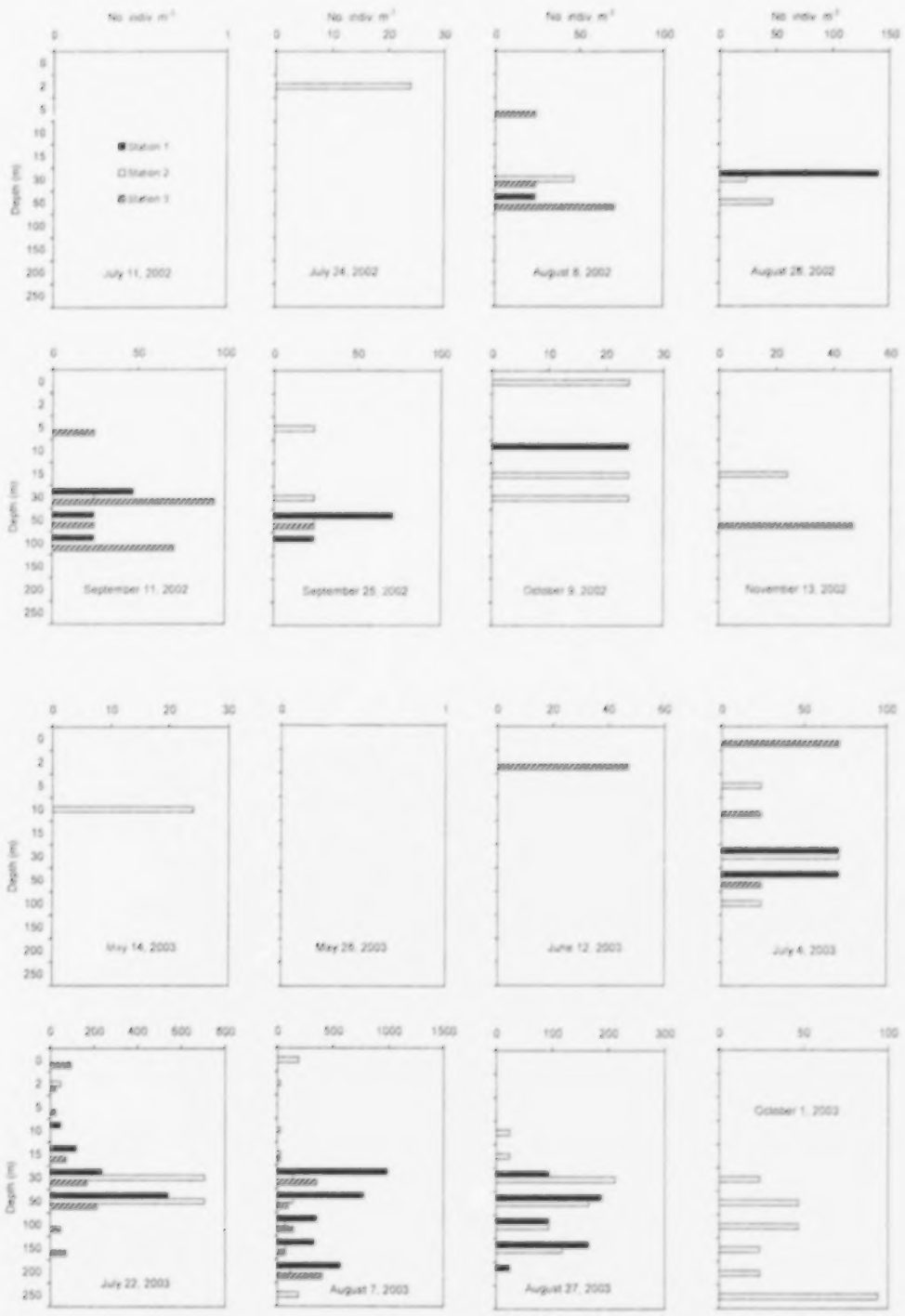

Figure 47. Vertical distribution of *Cyclops scutifer* adults by station. See text for details on stations and depths sampled on a particular date.

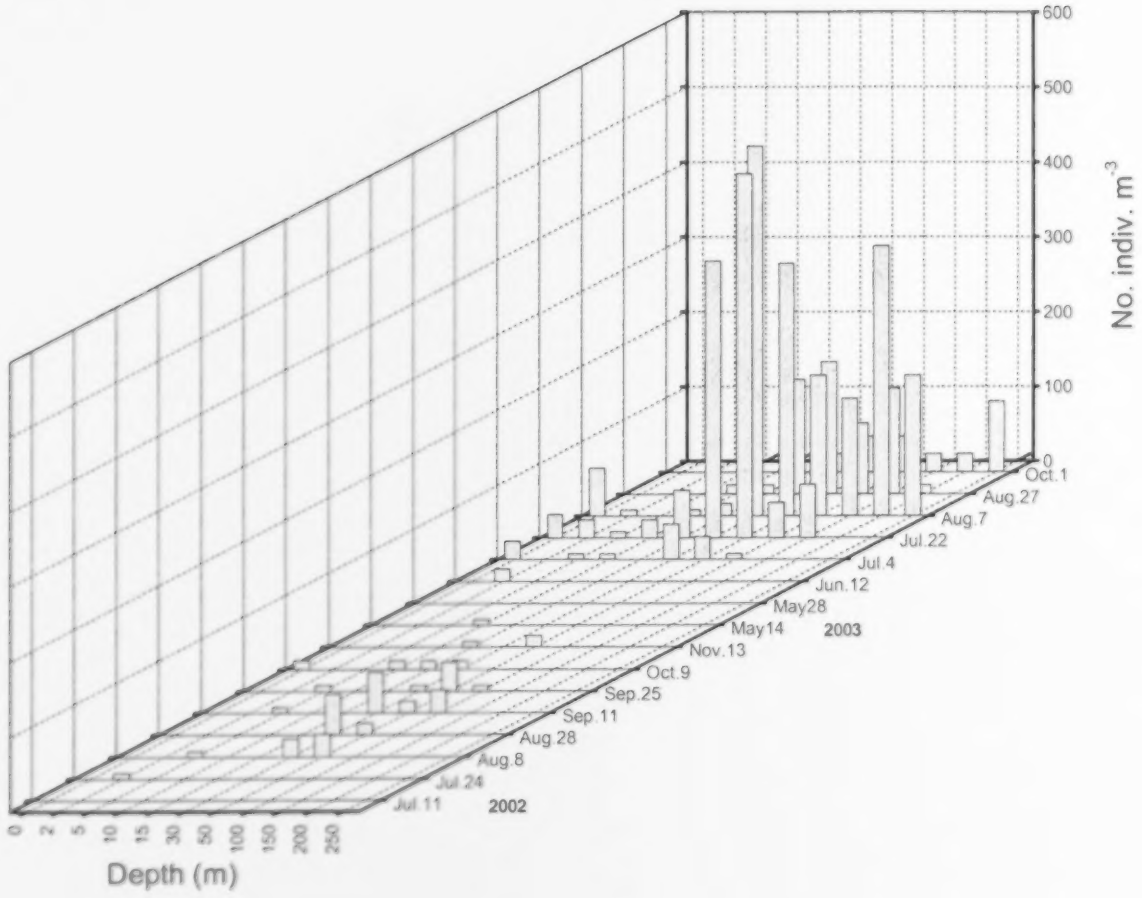

Figure 48. Vertical distribution of *Cyclops scutifer* adults (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

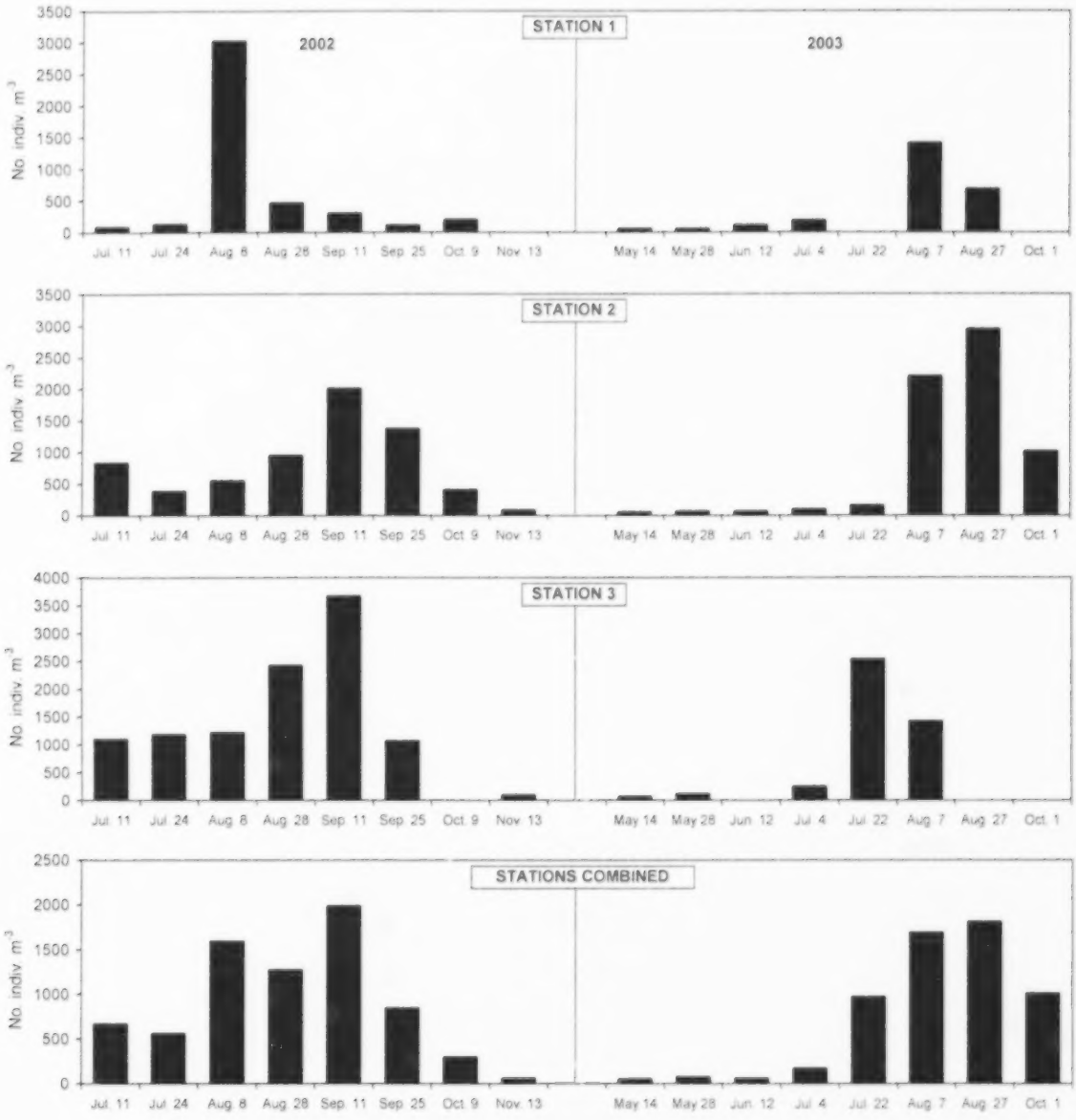

Figure 49. Seasonal distribution of total Rotifera (means of depths). See text for details on stations and depths sampled on a particular date.

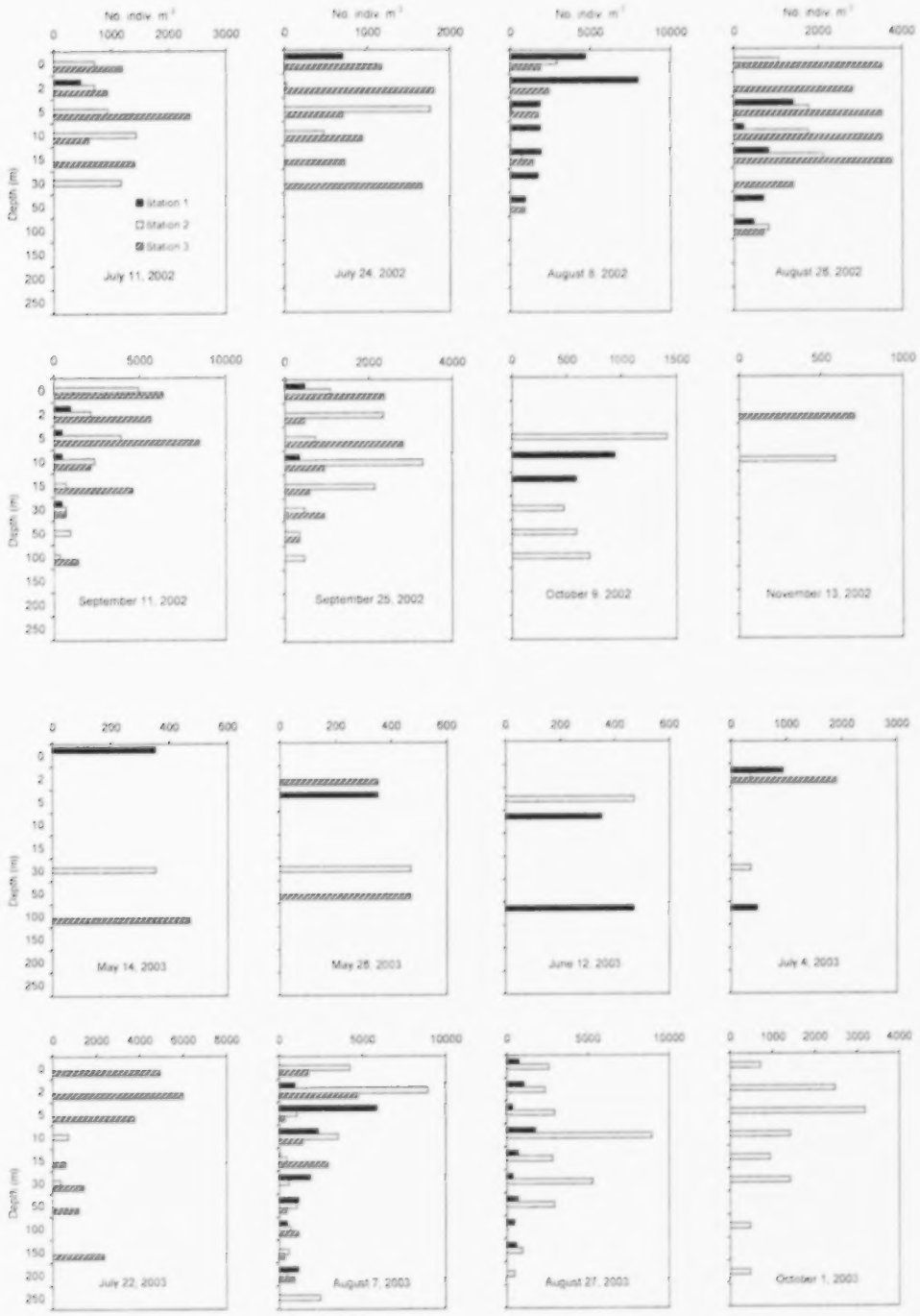

Figure 50. Vertical distribution of total Rotifera by station. See text for details on stations and depths sampled on a particular date.

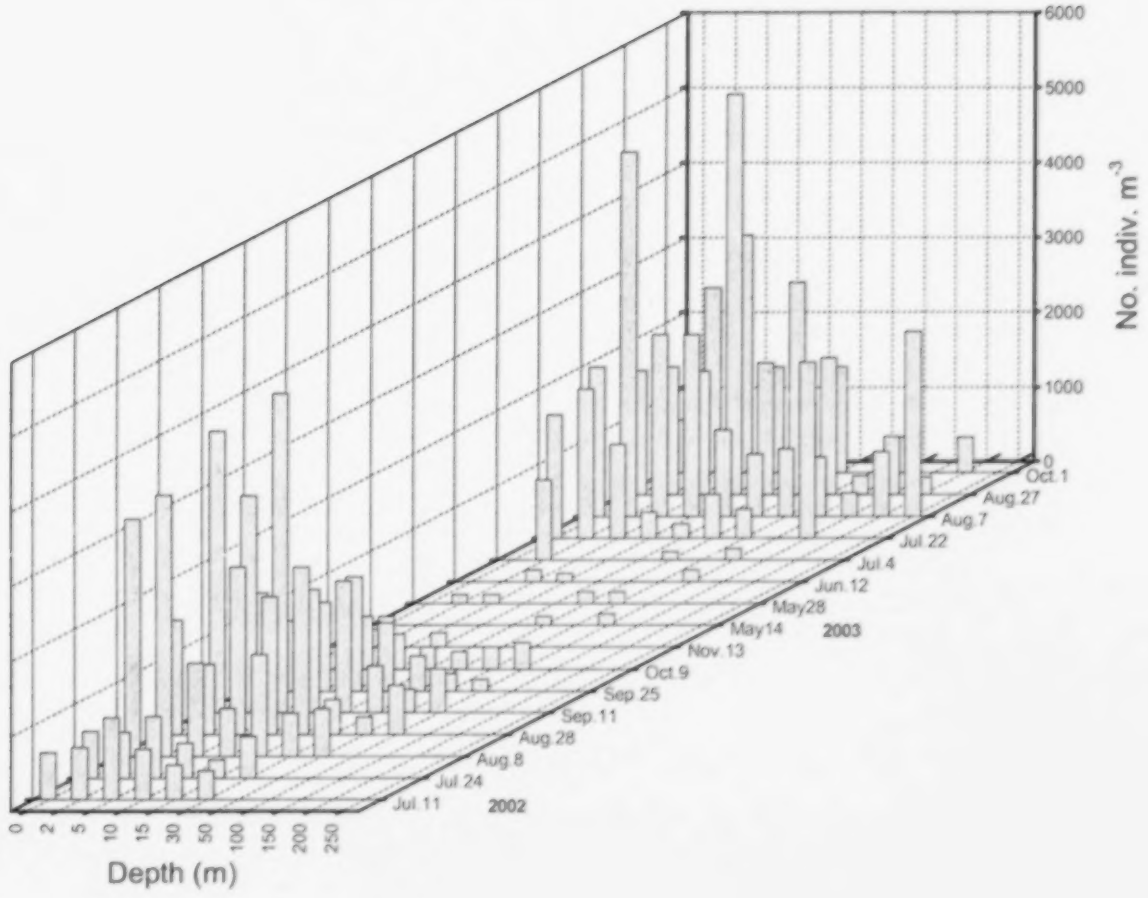

Figure 51. Vertical distribution of total Rotifera (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

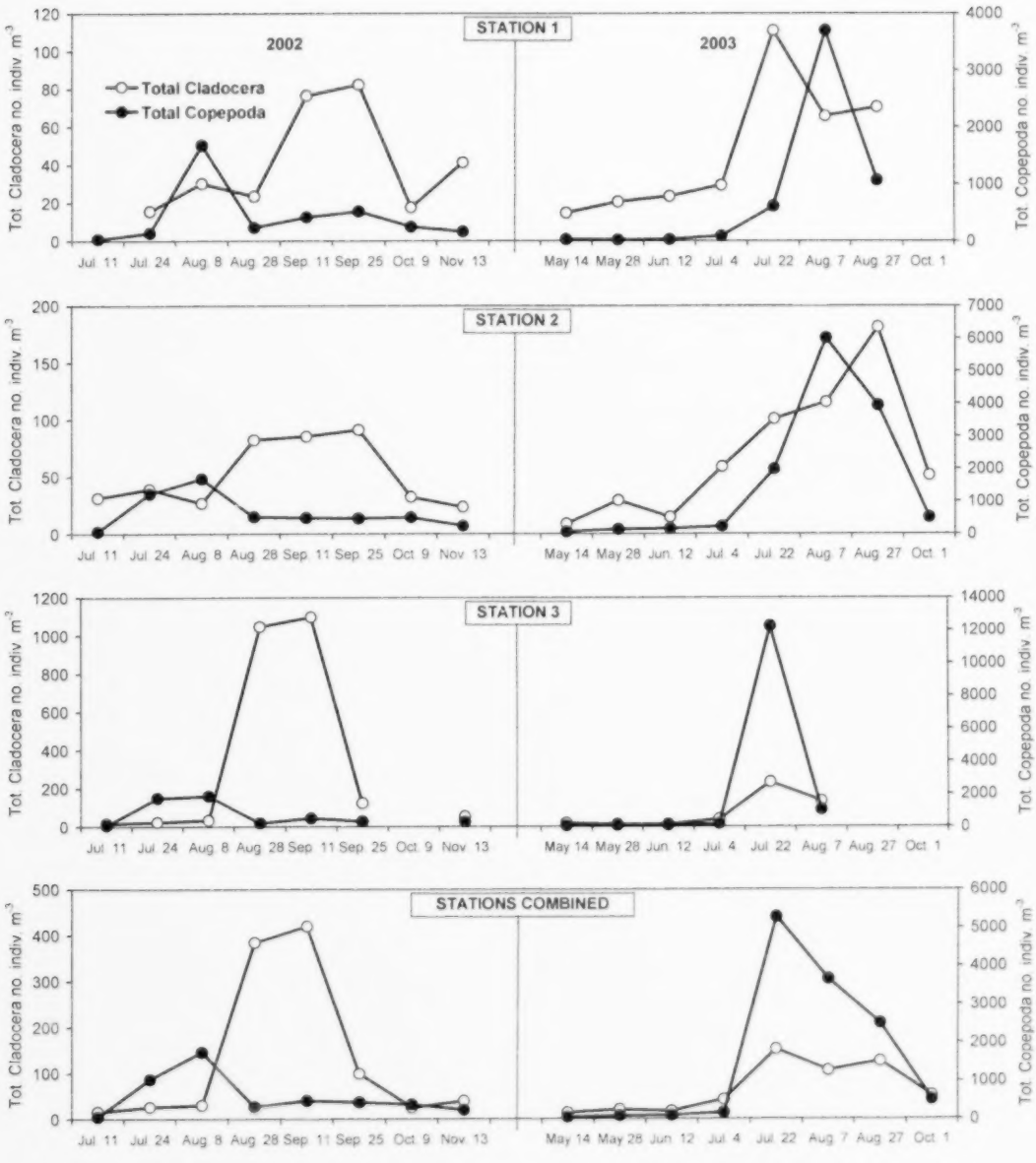
STATION 1
2002
2003
Total Cladocera
Total Copepoda
Tot. Cladocera no. indiv. m-3
Tot. Copepoda no. indiv. m-3
Jul. 11 Jul. 24 Aug. 8 Aug. 28 Sep. 11 Sep. 25 Oct. 9 Nov. 13
May 14 May 28 Jun. 12 Jul. 4 Jul. 22 Aug. 7 Aug. 27 Oct. 1
STATION 2
STATION 3
Tot. Cladocera no. indiv. m-2
STATIONS COMBINED

Figure 52. Seasonal distribution of total Cladocera and total Copepoda (nauplii excluded) (means of depths). See text for details on stations and depths sampled on a particular date.

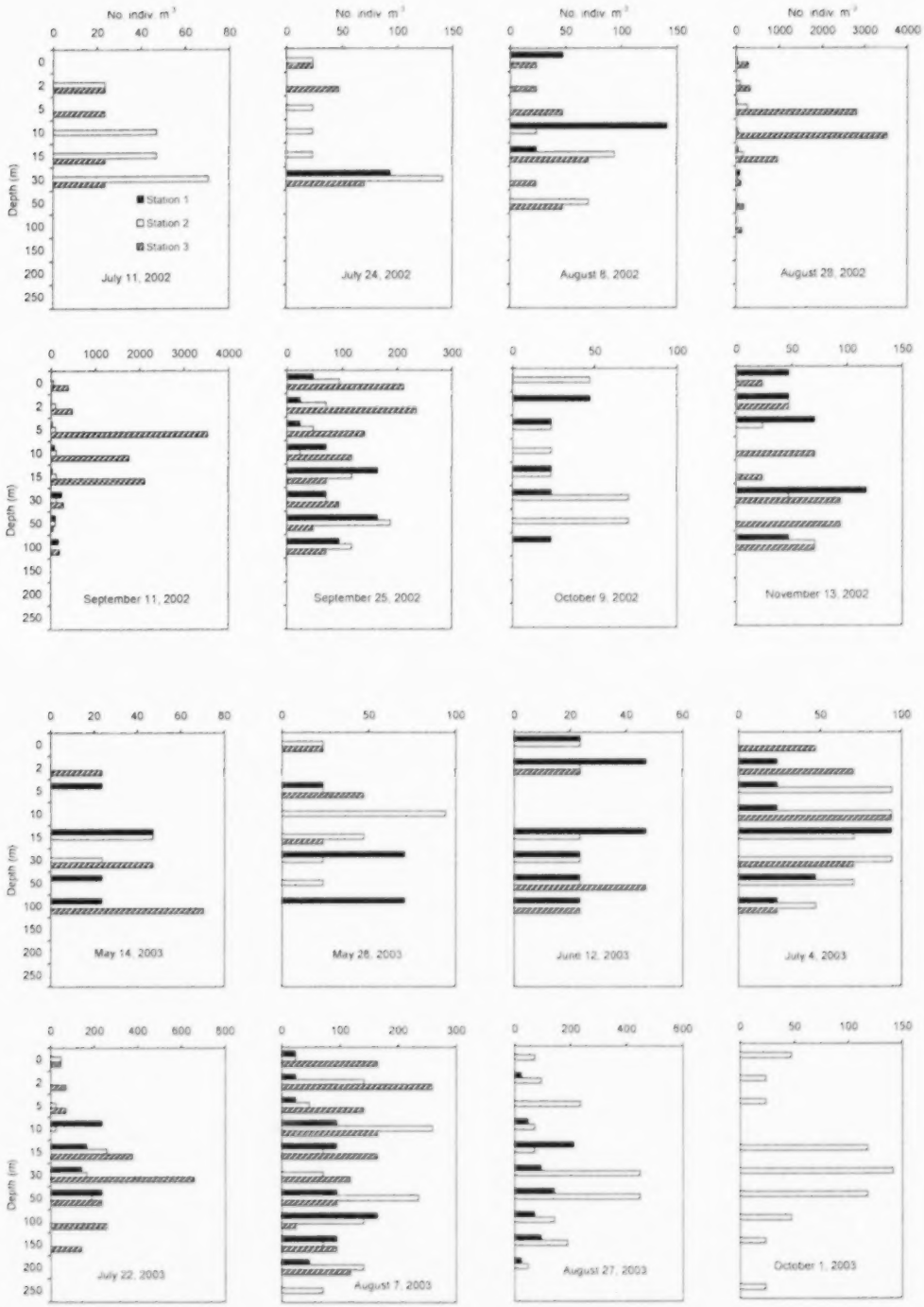

Figure 53. Vertical distribution of total Cladocera by station. See text for details on stations and depths sampled on a particular date.

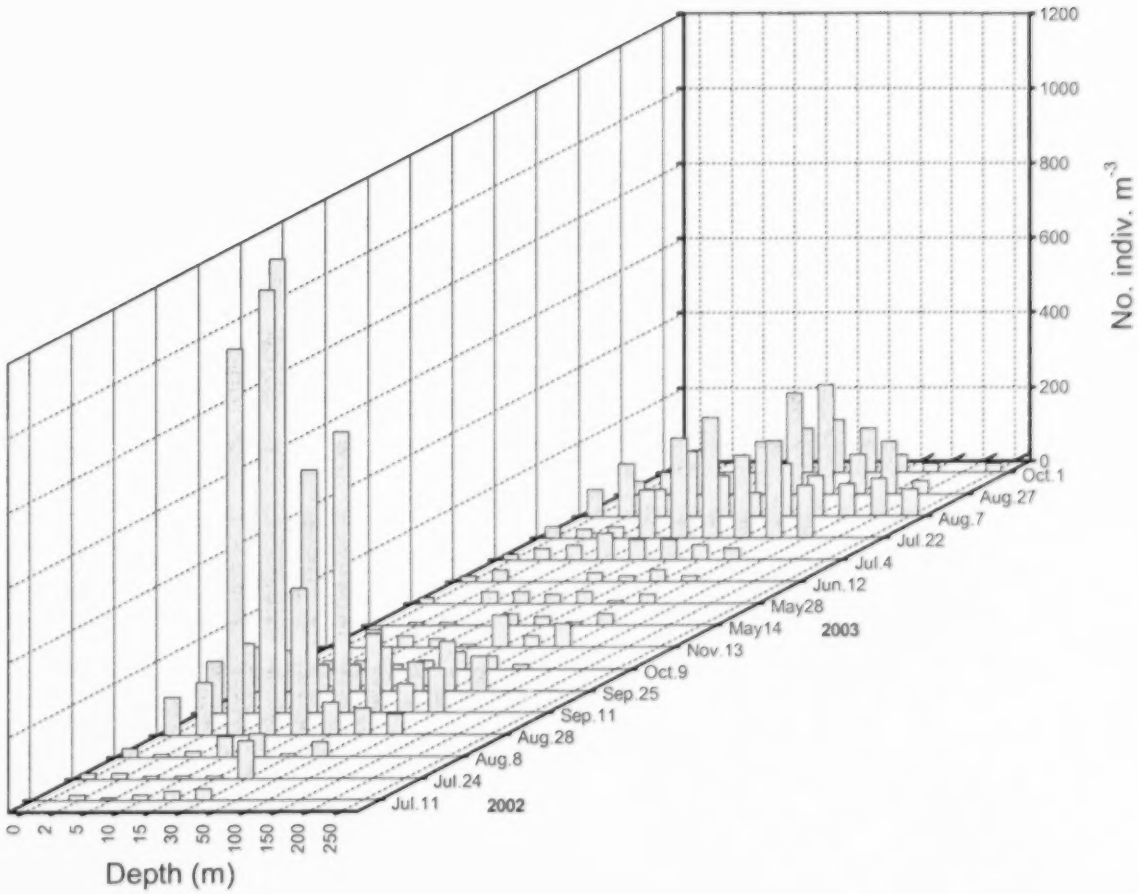

Figure 54. Vertical distribution of total Cladocera (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

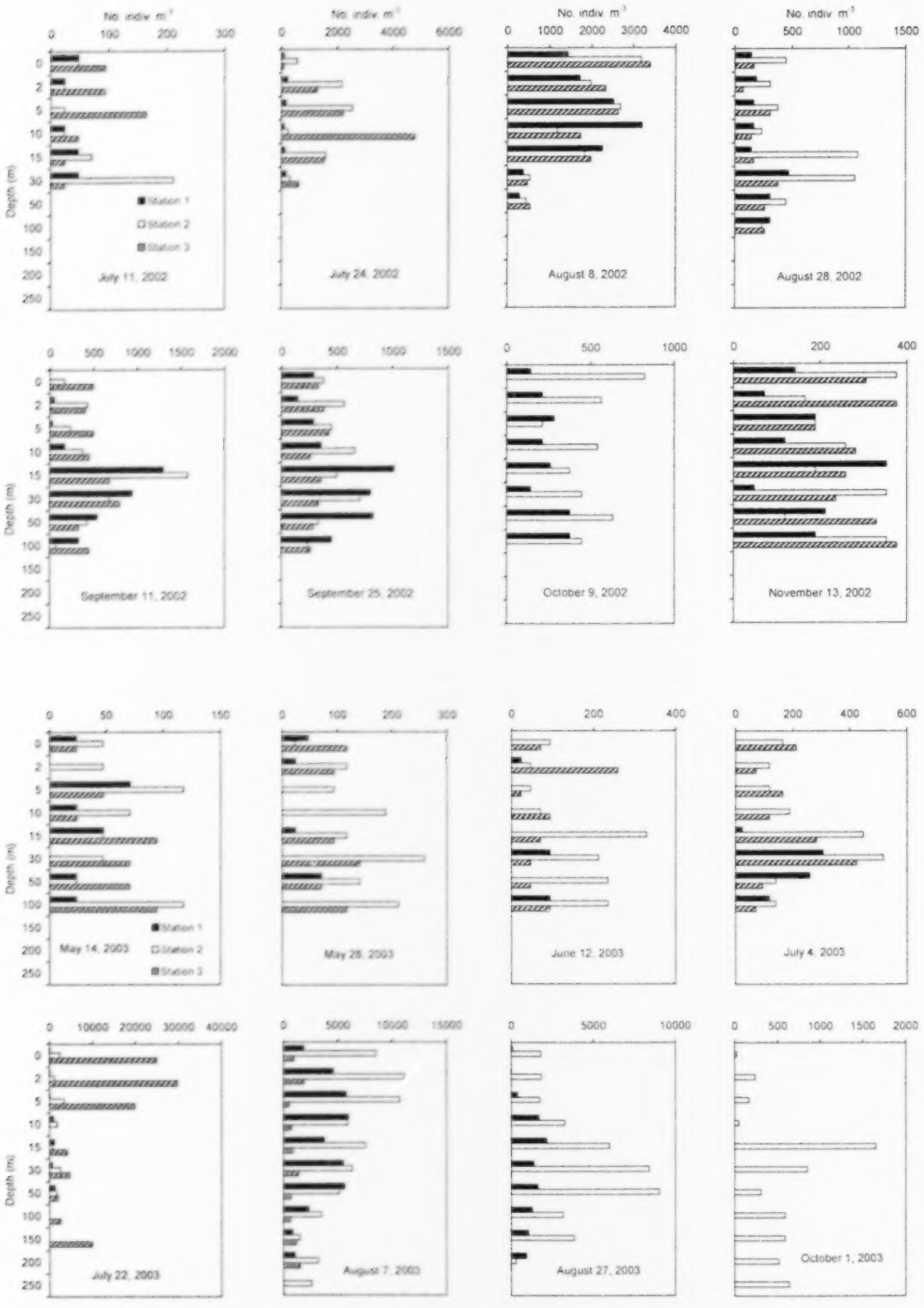

Figure 55. Vertical distribution of total Copepoda (nauplii excluded) by station. See text for details on stations and depths sampled on a particular date.

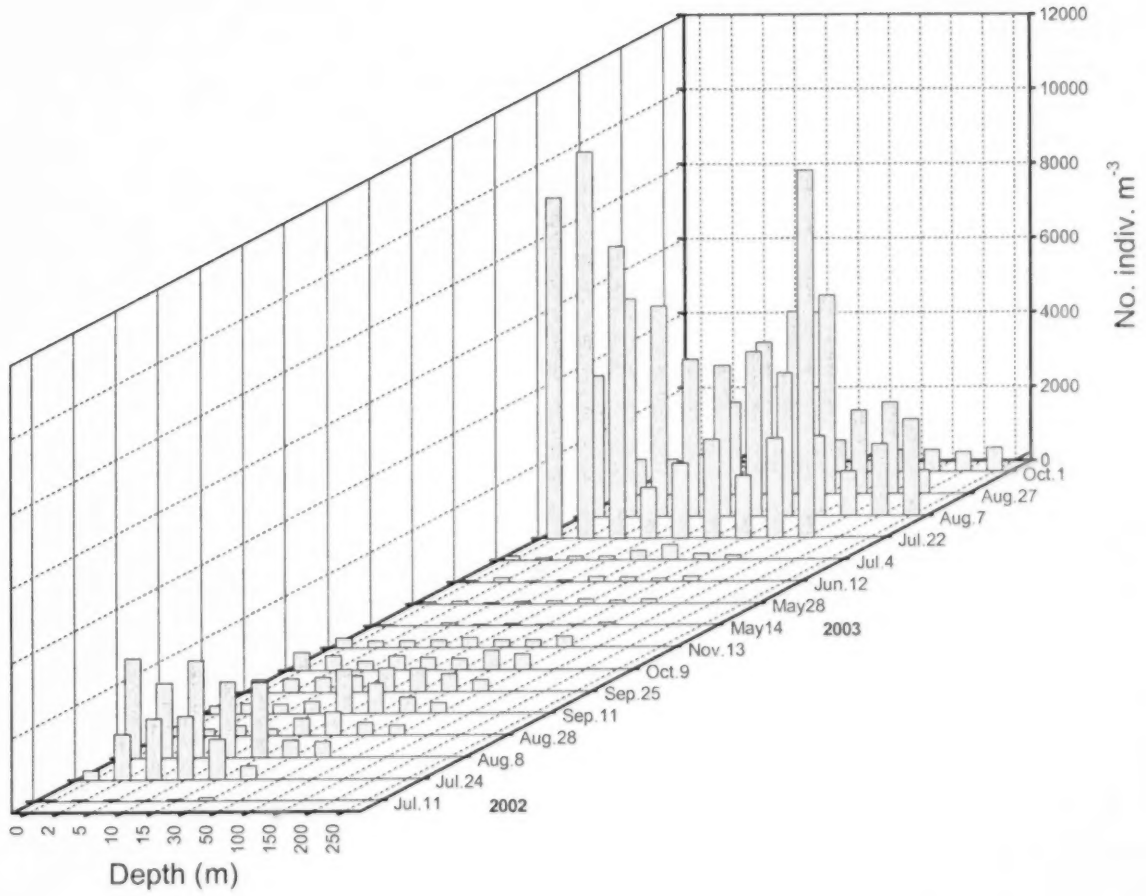

Figure 56. Vertical distribution of total Copepoda (nauplii excluded) (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

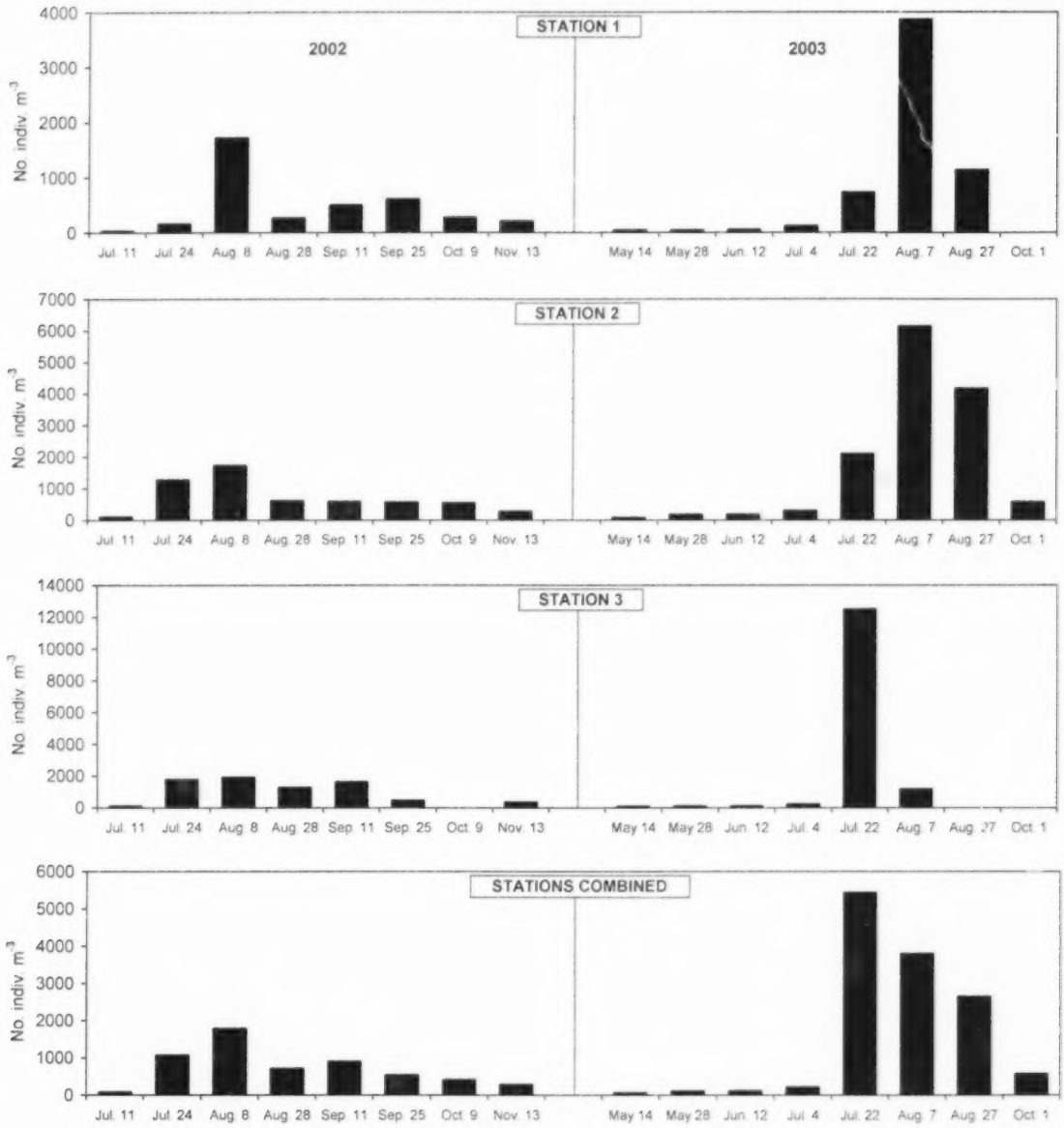

Figure 57. Seasonal distribution of total microcrustacea (nauplii excluded) (means of depths). See text for details on stations and depths sampled on a particular date.

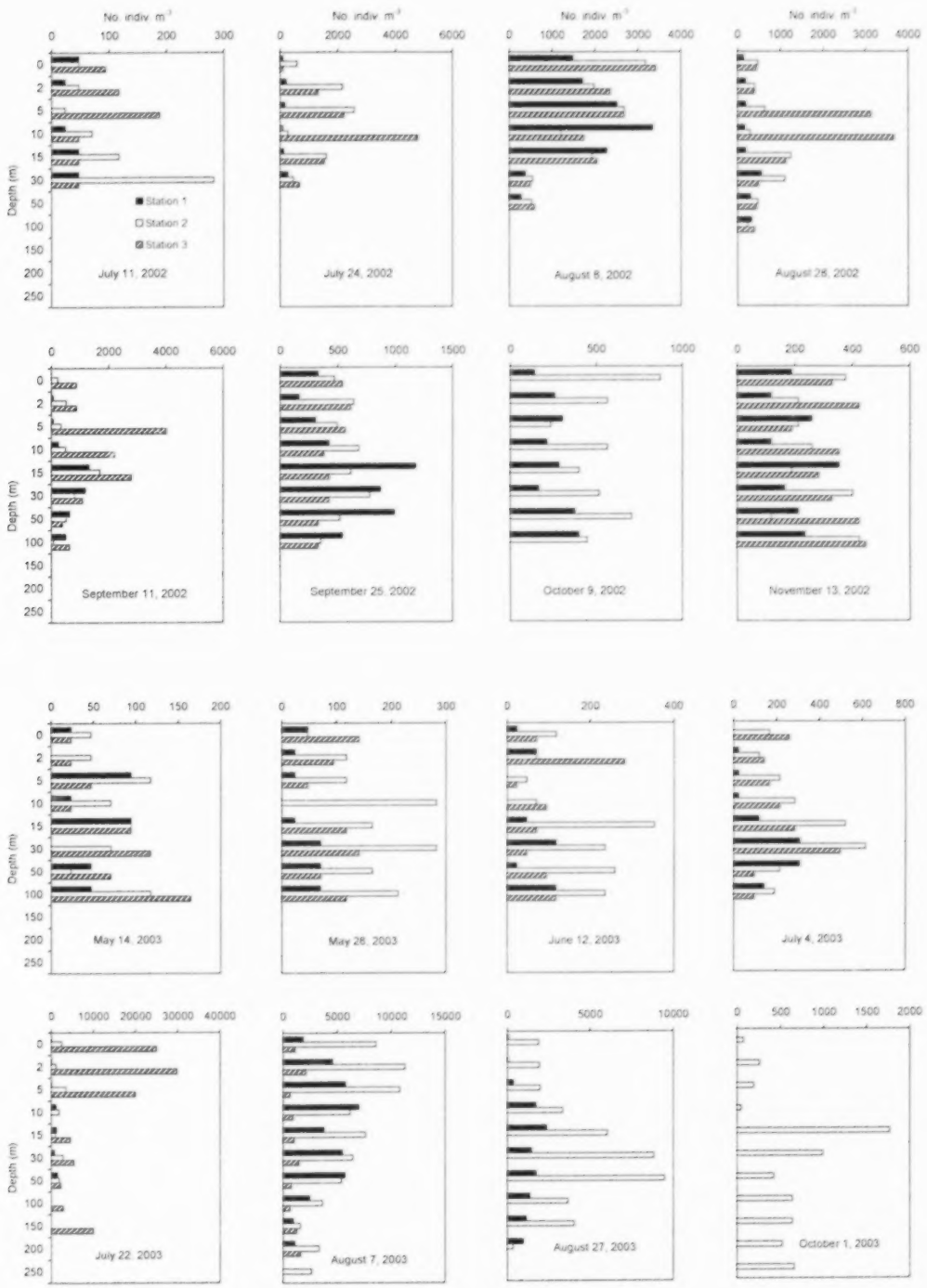

Figure 58. Vertical distribution of total microcrustacea (nauplii excluded) by station. See text for details on stations and depths sampled on a particular date.

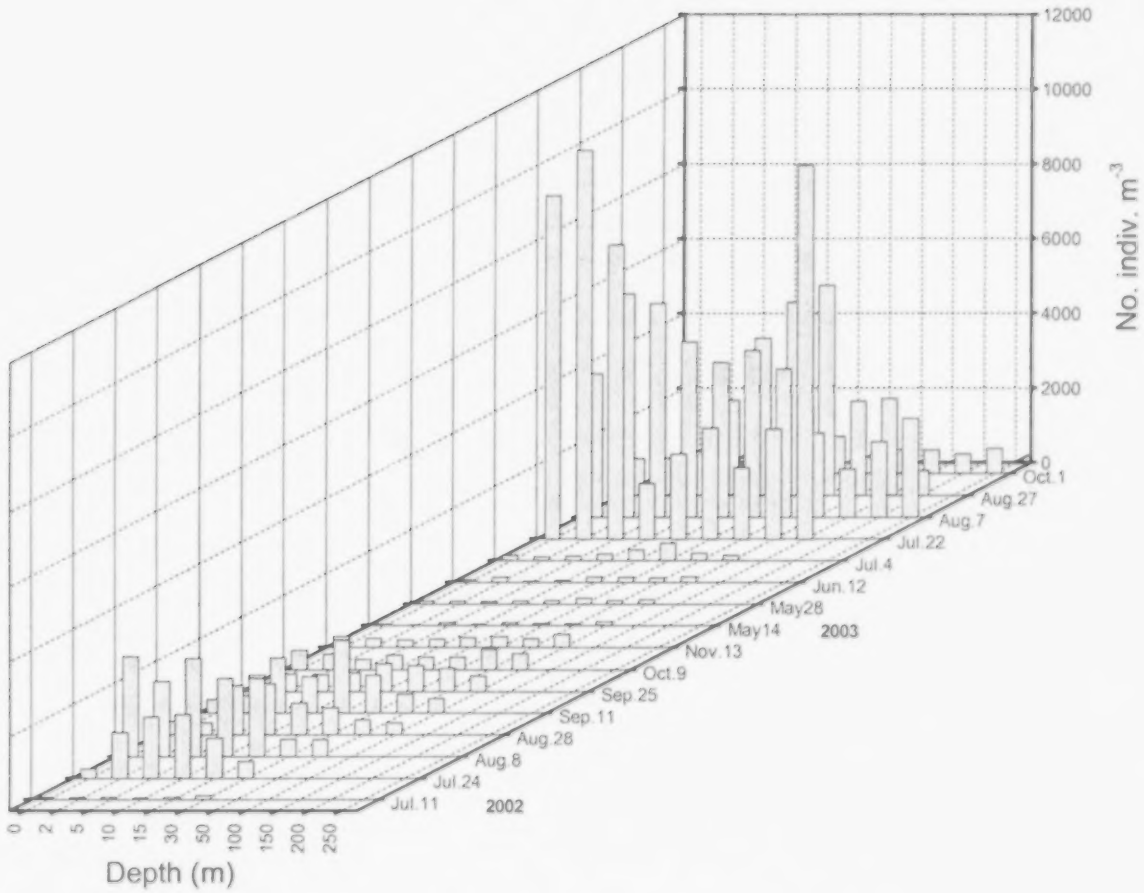

Figure 59. Vertical distribution of total microcrustacea (nauplii excluded) (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

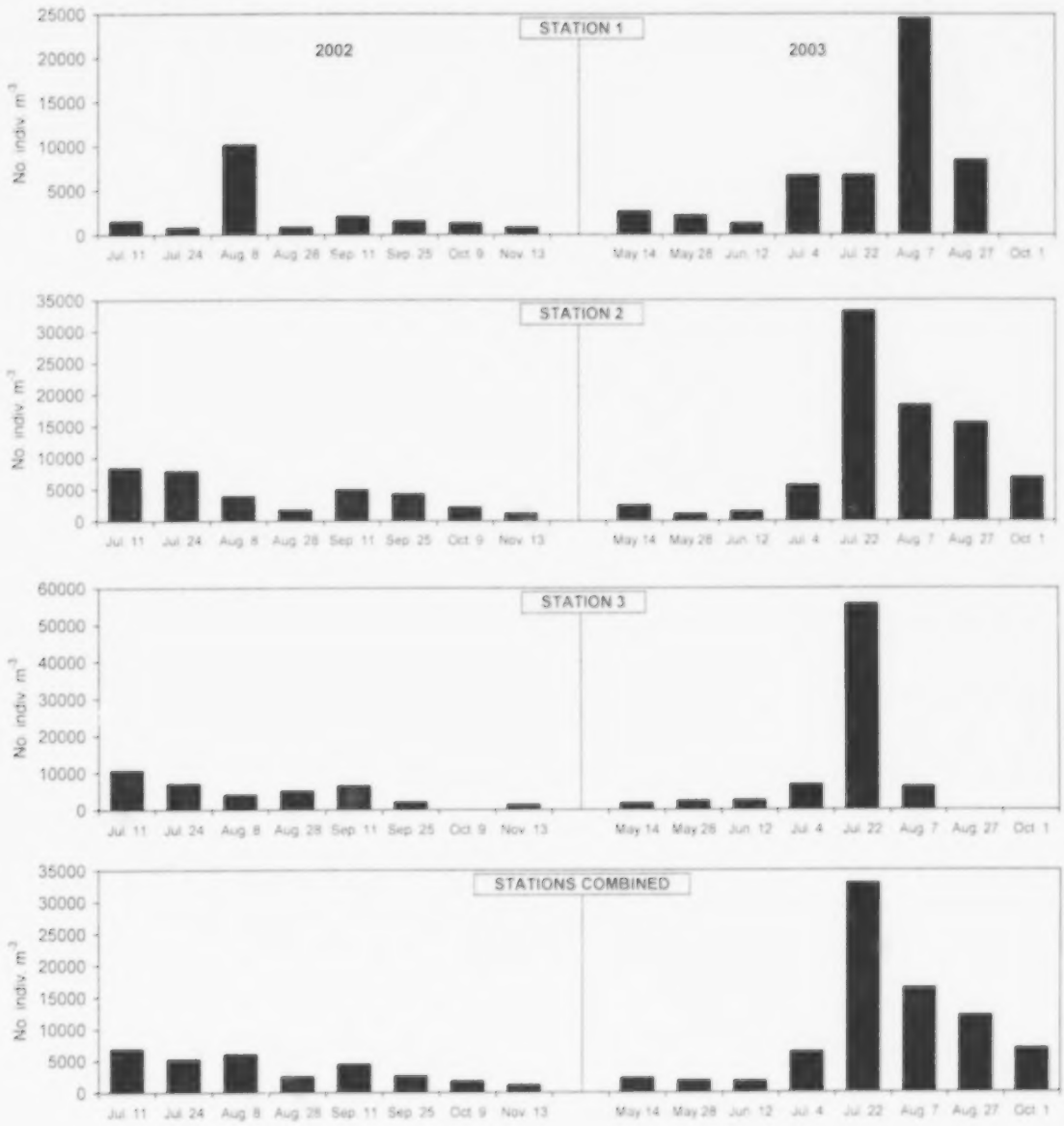

Figure 60. Seasonal distribution of total zooplankton (nauplii included) (means of depths). See text for details on stations and depths sampled on a particular date.

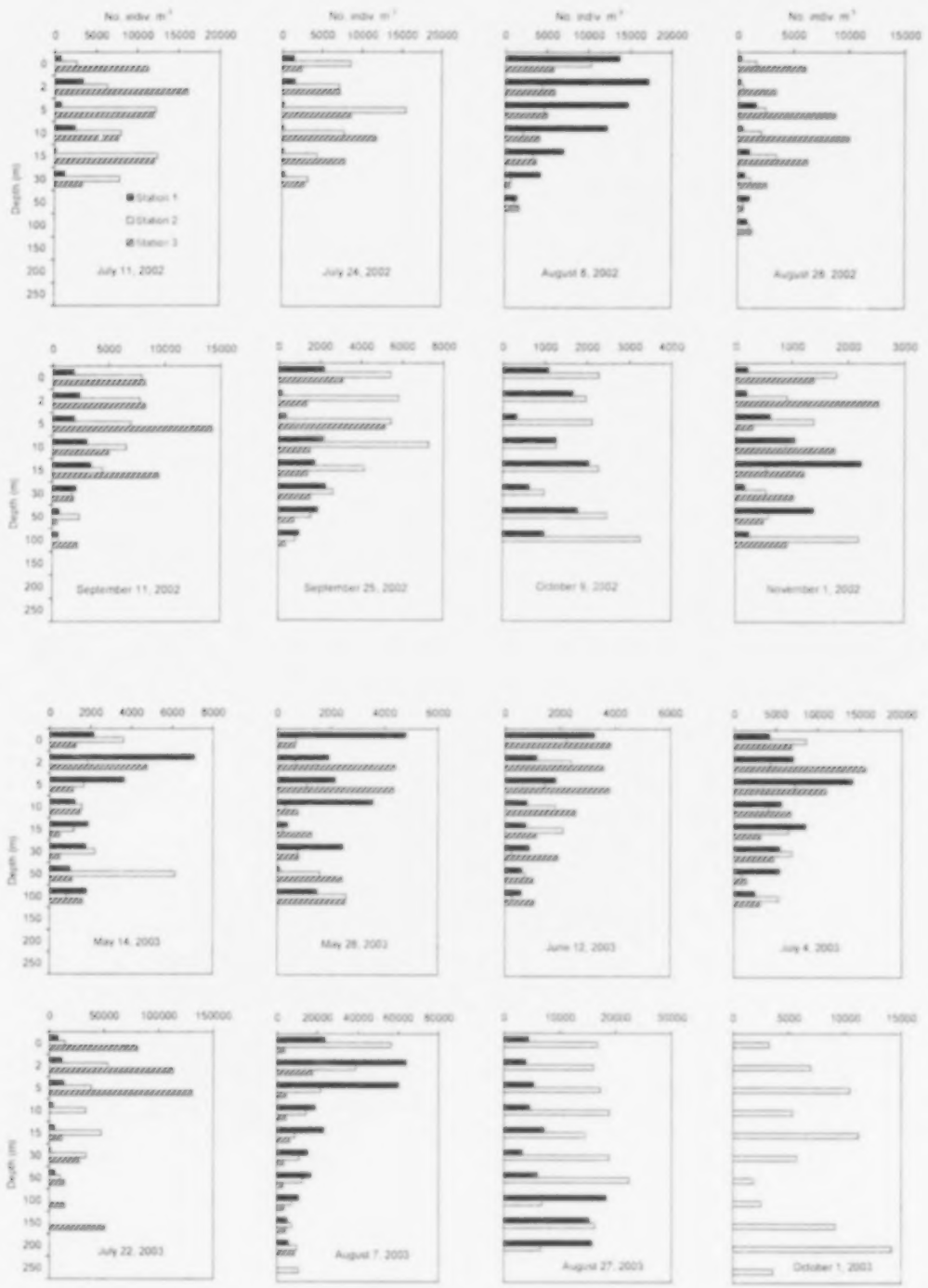

Figure 61. Vertical distribution of total zooplankton (nauplii included) by station. See text for details on stations and depths sampled on a particular date.

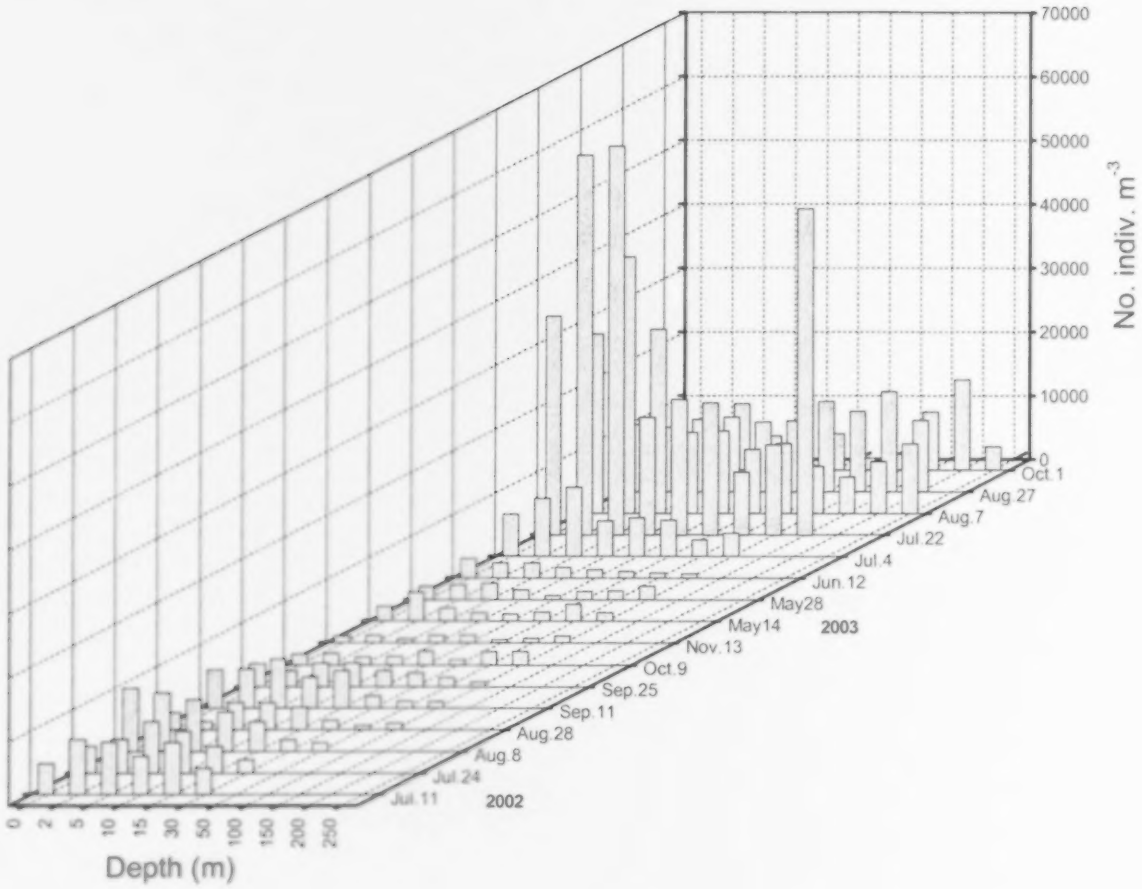

Figure 62. Vertical distribution of total zooplankton (nauplii included) (means of stations) on each sampling occasion. See text for details on stations and depths sampled on a particular date.

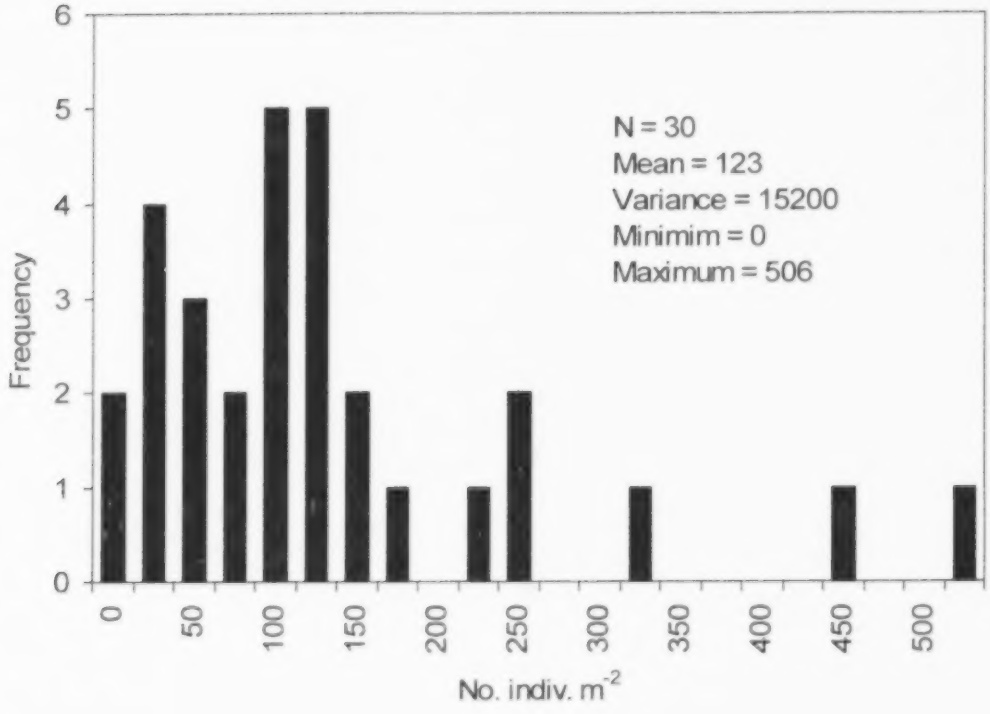

Figure 63. Frequency distribution of Chironomidae sampled in the main body of the lake at depths ranging from 199 to 280 m.

Appendix 1. List of net phytoplankton taxa encountered in this study.

Taxon
CYANOPHYTA
Anabaena Bory
Merismopedia Meyen
Oscillatoria Vaucher
Schizothrix lacustris A. Braun
CHLOROPHYTA
Arthrodesmus incus De Brébisson
Closterium setaceaum Ehrenberg
Dictyosphaerium Naegeli
Gloeocystis vesiculosa Naegeli
Gonatozygon kihnahani Archer
Micrasterias thomasiana Archer
Microspora Thuret
Mougeotia (C. A. Agardh) Wittrock
Spirogyra Link
Spondylosium De Brébisson
Staurastrum Meyen
Xanthidium Ehrenberg
CHRYSOPHYTA
Dinobryon bavaricum Hassall
Dinobryon cylindricum Imhof
Dinobryon sertularia Ehrenberg
BACILLARIOPHYTA
Asterionella formosa Hassall
Tabellaria fenestrata (Lyngbye) Kützing
Tabellaria flocculosa (Roth) Kützing
PYROPHYTA
Ceratium hirundinella (O. F. Müller) Dujardin
Peridinium limbatum (Stokes) Lemmermann

Appendix 2. List of zooplankton taxa encountered in this study.

Taxon
PROTOZOA
Codonella cratera (Leidy)
Vorticella Linnaeus
ROTIFERA
Asplancha priodonta (Gosse)
Conochilus unicornis (Rousselet)
Filinia Bory de St. Vincent
Gastropus Imhof
Kellicottia longispina (Kellicott)
Keratella Bory de St. Vincent
Keratella cochlearis (Gosse)
Keratella serrulata Ehrenberg
Keratella taurocephala (Myers)
Monostyla Ehrenberg
Pleosoma truncatum (Levander)
Polyarthra (Idelson)
Trichocerca Lamarck
CLADOCERA
Bosmina longirostris (O. F. Müller)
Daphnia catawba Coker
Eubosmina longispina (Leydig)
Holopedium gibberum Zaddach
Leptodora kindtii (Frocke)
Chydoridae
COPEPODA
Aglaodiaptomus spatulocrenatus Pearse
Cyclops scutifer Sars
Epischura lacustris Forbes
Leptodiaptomus minutus Lilljeborg
Harpactacoida
OSTRACODA
HYDRACARINA